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<p>(30) Priority Data:</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 40%;">08/201,109</td> <td style="width: 40%;">23 February 1994 (23.02.94)</td> <td style="width: 20%;">US</td> </tr> <tr> <td>08/218,934</td> <td>29 March 1994 (29.03.94)</td> <td>US</td> </tr> <tr> <td>08/222,795</td> <td>4 April 1994 (04.04.94)</td> <td>US</td> </tr> <tr> <td>08/224,483</td> <td>7 April 1994 (07.04.94)</td> <td>US</td> </tr> <tr> <td>08/228,041</td> <td>15 April 1994 (15.04.94)</td> <td>US</td> </tr> <tr> <td>08/227,958</td> <td>15 April 1994 (15.04.94)</td> <td>US</td> </tr> <tr> <td>08/245,736</td> <td>18 May 1994 (18.05.94)</td> <td>US</td> </tr> <tr> <td>08/271,280</td> <td>6 July 1994 (06.07.94)</td> <td>US</td> </tr> <tr> <td>08/291,932</td> <td>15 August 1994 (15.08.94)</td> <td>US</td> </tr> <tr> <td>08/291,433</td> <td>16 August 1994 (16.08.94)</td> <td>US</td> </tr> <tr> <td>08/292,620</td> <td>17 August 1994 (17.08.94)</td> <td>US</td> </tr> <tr> <td>08/293,520</td> <td>19 August 1994 (19.08.94)</td> <td>US</td> </tr> <tr> <td>08/300,000</td> <td>2 September 1994 (02.09.94)</td> <td>US</td> </tr> <tr> <td>08/303,039</td> <td>8 September 1994 (08.09.94)</td> <td>US</td> </tr> <tr> <td>08/311,486</td> <td>23 September 1994 (23.09.94)</td> <td>US</td> </tr> <tr> <td>08/311,749</td> <td>23 September 1994 (23.09.94)</td> <td>US</td> </tr> <tr> <td>08/314,397</td> <td>28 September 1994 (28.09.94)</td> <td>US</td> </tr> <tr> <td>08/316,771</td> <td>3 October 1994 (03.10.94)</td> <td>US</td> </tr> <tr> <td>08/319,492</td> <td>7 October 1994 (07.10.94)</td> <td>US</td> </tr> <tr> <td>08/321,993</td> <td>11 October 1994 (11.10.94)</td> <td>US</td> </tr> <tr> <td>08/334,847</td> <td>4 November 1994 (04.11.94)</td> <td>US</td> </tr> <tr> <td>08/337,608</td> <td>10 November 1994 (10.11.94)</td> <td>US</td> </tr> <tr> <td>08/345,516</td> <td>28 November 1994 (28.11.94)</td> <td>US</td> </tr> <tr> <td>08/357,577</td> <td>16 December 1994 (16.12.94)</td> <td>US</td> </tr> <tr> <td>08/363,233</td> <td>23 December 1994 (23.12.94)</td> <td>US</td> </tr> <tr> <td>08/380,734</td> <td>30 January 1995 (30.01.95)</td> <td>US</td> </tr> </table>	08/201,109	23 February 1994 (23.02.94)	US	08/218,934	29 March 1994 (29.03.94)	US	08/222,795	4 April 1994 (04.04.94)	US	08/224,483	7 April 1994 (07.04.94)	US	08/228,041	15 April 1994 (15.04.94)	US	08/227,958	15 April 1994 (15.04.94)	US	08/245,736	18 May 1994 (18.05.94)	US	08/271,280	6 July 1994 (06.07.94)	US	08/291,932	15 August 1994 (15.08.94)	US	08/291,433	16 August 1994 (16.08.94)	US	08/292,620	17 August 1994 (17.08.94)	US	08/293,520	19 August 1994 (19.08.94)	US	08/300,000	2 September 1994 (02.09.94)	US	08/303,039	8 September 1994 (08.09.94)	US	08/311,486	23 September 1994 (23.09.94)	US	08/311,749	23 September 1994 (23.09.94)	US	08/314,397	28 September 1994 (28.09.94)	US	08/316,771	3 October 1994 (03.10.94)	US	08/319,492	7 October 1994 (07.10.94)	US	08/321,993	11 October 1994 (11.10.94)	US	08/334,847	4 November 1994 (04.11.94)	US	08/337,608	10 November 1994 (10.11.94)	US	08/345,516	28 November 1994 (28.11.94)	US	08/357,577	16 December 1994 (16.12.94)	US	08/363,233	23 December 1994 (23.12.94)	US	08/380,734	30 January 1995 (30.01.95)	US	<p>(72) Inventors: <b>STINCHCOMB, Dan, T.; 7203 Old Post Road, Boulder, CO 80301 (US). CHOWRIRA, Bharat; 3250 O'Neal Circle, B-25, Boulder, CO 80301 (US). DIRENZO, Anthony; 1197 Ravenwood Road, Boulder, CO 80303 (US). DRAPER, Kenneth, G.; 4619 Cloud Ct., Boulder, CO 80301 (US). DUDYCZ, Lech, W.; 24 A Gates Road, Worcester, MA 01603 (US). GRIMM, Susan; 6968 1/2 S. Boulder Road, Boulder, CO 80303 (US). KARPEISKY, Alexander; 5121 Williams Fork Trail #209, Boulder, CO 80301 (US). KISICH, Kevin; 2451 Jonquil Circle, Lafayette, CO 80026 (US). MATULIC-ADAMIC, Jasenka; 760 South 42nd Street, Boulder, CO 80303 (US). McSWIGGEN, James, A.; 4866 Franklin Drive, Boulder, CO 80301 (US). MODAK, Anil; 3855 Hauptman Court, Boulder, CO 80301 (US). PAVCO, Pamela; 705 Barberry Circle, Lafayette, CO 80026 (US). BEIGELMAN, Leonid; 5530 Colt Drive, Longmont, CO 80503 (US). SULLIVAN, Sean, M.; 850 Marina Village Parkway, Alameda, CA 94501 (US). SWEEDLER, David; 956 St. Andrews Lane, Louisville, CO 80027 (US). THOMPSON, James, D.; 2925 Glenwood Drive #301, Boulder, CO 80301 (US). TRACZ, Danuta; 6200 Habitat #3029, Boulder, CO 80301 (US). USMAN, Nassim; 2954 Kalmia #37, Boulder, CO 80304 (US). WINCOTT, Francine, E.; 7920 N. 95th Street, Longmont, CO 80501 (US). WOOLF, Tod; 18 Fairview Avenue, Watertown, MA 02172 (US).</b></p> <p>(74) Agents: <b>WARBURG, Richard, J. et al; Lyon &amp; Lyon, Suite 4700, 633 West Fifth Street, Los Angeles, CA 90071-2066 (US).</b></p> <p>(81) Designated States: <b>AU, CA, JP, KR, MX, European patent (AT, BE, CH, DE, DK, ES, FR, GR, IE, IT, LU, MC, NL, PT, SE).</b></p> <p>Published Without international search report and to be republished upon receipt of that report.</p>	
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<p>(71) Applicant: <b>RIBOZYME PHARMACEUTICALS, INC. [US/US]; 2950 Wilderness Place, Boulder, CO 80301 (US).</b></p>																																																																																
<p>(54) Title: <b>METHOD AND REAGENT FOR INHIBITING THE EXPRESSION OF DISEASE RELATED GENES</b></p> <div style="text-align: center; margin-top: 10px;"> <p>Substrate RNA</p> </div>																																																																																

**NUC 37604**

(57) Abstract

Enzymatic RNA molecules which cleave ICAM-1 mRNA, IL-5 mRNA, *rel A* mRNA, TNF- $\alpha$  mRNA, RSV mRNA or RSV genomic RNA, or CML associated mRNA, and use of these molecules for the treatment of pathological conditions related to those mRNA-levels; ribonucleosides or nucleotides modified in 2', 3' or 5', methods for their synthesis, purification and deprotection; vectors containing multiple enzymatic nucleic acids, optionally in chimeric form with tRNAs; method for introducing enzymatic nucleic acids into cells by forming a complex with a second nucleic acid, where the complex is capable of taking an R-loop base-paired structure; method for altering a mutant nucleic acid *in vivo* by hybridization with an oligonucleotide capable of activating dsRNA deaminase, comprising an enzymatic activity or a chemical mutagen. Further are disclosed trans-cleaving or -ligating hairpin ribozymes lacking a substrate RNA moiety, as well as hammerhead ribozymes having an interconnecting loop between base pairs in stem II.

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METHOD AND REAGENT FOR INHIBITING THE EXPRESSION  
OF DISEASE RELATED GENESBackground of the Invention

This invention relates to reagents useful as inhibitors of gene expression relating to diseases such as inflammatory or autoimmune disorders, chronic myelogenous leukemia, or respiratory tract illness.

5

Summary of the Invention

The invention features novel enzymatic RNA molecules, or ribozymes, and methods for their use for inhibiting the expression of disease related genes, e.g., ICAM-1, IL-5, *relA*, TNF- $\alpha$ , p210 *bcr-abl*, and respiratory syncytial virus genes. Such ribozymes can be used in a method for  
10 treatment of diseases caused by the expression of these genes in man and other animals, including other primates.

Ribozymes are RNA molecules having an enzymatic activity which is able to repeatedly cleave other separate RNA molecules in a nucleotide base sequence specific manner. Such enzymatic RNA molecules can be  
15 targeted to virtually any RNA transcript, and efficient cleavage has been achieved *in vitro*. Kim et al., 84 Proc. Natl. Acad. Sci. USA 8788, 1987; Haseloff and Gerlach, 334 Nature 585, 1988; Cech, 260 JAMA 3030, 1988; and Jefferies et al., 17 Nucleic Acids Research 1371, 1989.

Six basic varieties of naturally-occurring enzymatic RNAs are known  
20 presently. Each can catalyze the hydrolysis of RNA phosphodiester bonds in trans (and thus can cleave other RNA molecules) under physiological conditions. Table 1 summarizes some of the characteristics of these ribozymes.

Ribozymes act by first binding to a target RNA. Such binding occurs  
25 through the target RNA binding portion of a ribozyme which is held in close proximity to an enzymatic portion of the RNA which acts to cleave the target RNA. Thus, the ribozyme first recognizes and then binds a target RNA through complementary base-pairing, and once bound to the correct site, acts enzymatically to cut the target RNA. Strategic cleavage of such a  
30 target RNA will destroy its ability to direct synthesis of an encoded protein. After a ribozyme has bound and cleaved its RNA target it is released from that RNA to search for another target and can repeatedly bind and cleave new targets.

The enzymatic nature of a ribozyme is advantageous over other technologies, such as antisense technology (where a nucleic acid molecule simply binds to a nucleic acid target to block its translation) since the effective concentration of ribozyme necessary to effect a therapeutic treatment is lower than that of an antisense oligonucleotide. The advantage reflects the ability of the ribozyme to act enzymatically. Thus, a single ribozyme molecule is able to cleave many molecules of target RNA. In addition, the ribozyme is a highly specific inhibitor, with the specificity of inhibition depending not only on the base pairing mechanism of binding, but also on the mechanism by which the molecule inhibits the expression of the RNA to which it binds. That is, the inhibition is caused by cleavage of the RNA target and so specificity is defined as the ration of the rate of cleavage of the targeted RNA over the rate of cleavage of non-targeted RNA. This cleavage mechanism is dependent upon factors additional to those involved in base pairing. Thus, it is thought that the specificity of action of a ribozyme is greater than that of antisense oligonucleotide binding the same RNA site. With their catalytic activity and increased site specificity, ribozymes represent more potent and safe therapeutic molecules than antisense oligonucleotides.

Thus, in a first aspect, this invention relates to ribozymes, or enzymatic RNA molecules, directed to cleave RNA species encoding ICAM-1, IL-5, relA, TNF- $\alpha$ , p210<sup>bcr-abl</sup>, or RSV proteins. In particular, applicant describes the selection and function of ribozymes capable of cleaving these RNAs and their use to reduce levels of ICAM-1, IL-5, relA, TNF- $\alpha$ , p210 bor-abl or RSV proteins in various tissues to treat the diseases discussed herein. Such ribozymes are also useful for diagnostic uses.

Applicant indicates that these ribozymes are able to inhibit expression of ICAM-1, IL-5, rel A, TNF- $\alpha$ , p210<sup>bcr-abl</sup>, or RSV genes and that the catalytic activity of the ribozymes is required for their inhibitory effect. Those of ordinary skill in the art, will find that it is clear from the examples described that other ribozymes that cleave target ICAM-1, IL-5, rel A, TNF- $\alpha$ , p210<sup>bcr-abl</sup>, or RSV encoding mRNAs may be readily designed and are within the invention.

These chemically or enzymatically synthesized RNA molecules contain substrate binding domains that bind to accessible regions of their target mRNAs. The RNA molecules also contain domains that catalyze the

cleavage of RNA. Upon binding, the ribozymes cleave the target encoding mRNAs, preventing translation and protein accumulation. In the absence of the expression of the target gene, a therapeutic effect may be observed.

By "gene" is meant to refer to either the protein coding regions of the cognate mRNA, or any regulatory regions in the RNA which regulate synthesis of the protein or stability of the mRNA; the term also refers to those regions of an mRNA which encode the ORF of a cognate polypeptide product, and the proviral genome.

By "enzymatic RNA molecule" it is meant an RNA molecule which has complementarity in a substrate binding region to a specified gene target, and also has an enzymatic activity which is active to specifically cleave RNA in that target. That is, the enzymatic RNA molecule is able to intermolecularly cleave RNA and thereby inactivate a target RNA molecule. This complementarity functions to allow sufficient hybridization of the enzymatic RNA molecule to the target RNA to allow the cleavage to occur. One hundred percent complementarity is preferred, but complementarity as low as 50-75% may also be useful in this invention. By "equivalent" RNA to a virus is meant to include those naturally occurring viral encoded RNA molecules associated with viral caused diseases in various animals, including humans, cats, simians, and other primates. These viral or viral-encoded RNAs have similar structures and equivalent genes to each other.

By "complementarity" it is meant a nucleic acid that can form hydrogen bond(s) with other RNA sequence by either traditional Watson-Crick or other non-traditional types (for example, Hoogsteen type) of base-paired interactions.

In preferred embodiments of this invention, the enzymatic nucleic acid molecule is formed in a hammerhead or hairpin motif, but may also be formed in the motif of a hepatitis delta virus, group I intron or RNaseP RNA (in association with an RNA guide sequence) or *Neurospora* VS RNA. Examples of such hammerhead motifs are described by Rossi *et al.*, 1992, Aids Research and Human Retroviruses, 8,183, of hairpin motifs by Hampel and Tritz, 1989 Biochemistry, 28, 4929, EP 0360257 and Hampel *et al.*, 1990, Nucleic Acids Res. 18,299 and an example of the hepatitis delta virus motif is described by Perotta and Been, 1992 Biochemistry, 31 16 of the RNaseP motif by Guerrier-Takada *et al.*, 1983 Cell, 35 849,

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expressed in eukaryotic cells from the appropriate DNA or RNA vector. The activity of such ribozymes can be augmented by their release from the primary transcript by a second ribozyme (Draper et al., PCT WO93/23569, and Sullivan et al., PCT WO94/02595, both hereby incorporated in their  
5 totality by reference herein; Ohkawa, J., et al., 1992, Nucleic Acids Symp. Ser. 27, 15-6; Taira, K. et al., Nucleic Acids Res., 19, 5125-30; Ventura, M., et al., 1993, Nucleic Acids Res., 21, 3249-55, Chowrira et al., 1994 J. Biol. Chem., 269, 25856 ).

By "inhibit" is meant that the activity or level of ICAM-1, Rel A, IL-5,  
10 TNF- $\alpha$ , p210<sup>bcr-abl</sup> or RSV encoding mRNA is reduced below that observed in the absence of the ribozyme, and preferably is below that level observed in the presence of an inactive RNA molecule able to bind to the same site on the mRNA, but unable to cleave that RNA.

Such ribozymes are useful for the prevention of the diseases and  
15 conditions discussed above, and any other diseases or conditions that are related to the level of ICAM-1, IL-5, Rel A, TNF- $\alpha$ , p210<sup>bcr-abl</sup> or RSV protein or activity in a cell or tissue. By "related" is meant that the inhibition of ICAM-1, IL-5, Rel A, TNF- $\alpha$ , p210<sup>bcr-abl</sup> or RSV mRNA translation, and thus reduction in the level of, ICAM-1, IL-5, Rel A, TNF- $\alpha$ , p210<sup>bcr-abl</sup> or  
20 RSV proteins will relieve to some extent the symptoms of the disease or condition.

Ribozymes are added directly, or can be complexed with cationic lipids, packaged within liposomes, or otherwise delivered to target cells. The RNA or RNA complexes can be locally administered to relevant tissues  
25 through the use of a catheter, infusion pump or stent, with or without their incorporation in biopolymers. In preferred embodiments, the ribozymes have binding arms which are complementary to the sequences in Tables 2,3,6-9, 11, 13, 15-23, 27, 28, 31, 33, 34, 36 and 37.

Examples of such ribozymes are shown in Tables 4-8, 10, 12, 14-16,  
30 19-22, 24, 26-28, 30, 32, 34 and 36-38. Examples of such ribozymes consist essentially of sequences defined in these Tables. By "consists essentially of" is meant that the active ribozyme contains an enzymatic center equivalent to those in the examples, and binding arms able to bind mRNA such that cleavage at the target site occurs. Other sequences may  
35 be present which do not interfere with such cleavage.

Those in the art will recognize that these sequences are representative only of many more such sequences where the enzymatic portion of the ribozyme (all but the binding arms) is altered to affect activity. For example, stem-loop II sequence of hammerhead ribozymes listed in the above identified Tables can be altered (substitution, deletion, and/or insertion) to contain any sequences provided a minimum of two base-paired stem structure can form. Similarly, stem-loop IV sequence of hairpin ribozymes listed in the above identified Tables can be altered (substitution, deletion, and/or insertion) to contain any sequence, provided a minimum of two base-paired stem structure can form. The sequence listed in the above identified Tables may be formed of ribonucleotides or other nucleotides or non-nucleotides. Such ribozymes are equivalent to the ribozymes described specifically in the Tables.

In another aspect of the invention, ribozymes that cleave target molecules and inhibit ICAM-1, IL-5, Rel A, TNF- $\alpha$ , p210<sup>bcr-abl</sup> or RSV gene expression are expressed from transcription units inserted into DNA, RNA, or viral vectors. Another means of accumulating high concentrations of a ribozyme(s) within cells is to incorporate the ribozyme-encoding sequences into a DNA or RNA expression vector. Transcription of the ribozyme sequences are driven from a promoter for eukaryotic RNA polymerase I (pol I), RNA polymerase II (pol II), or RNA polymerase III (pol III). Transcripts from pol II or pol III promoters will be expressed at high levels in all cells; the levels of a given pol II promoter in a given cell type will depend on the nature of the gene regulatory sequences (enhancers, silencers, etc.) present nearby. Prokaryotic RNA polymerase promoters are also used, providing that the prokaryotic RNA polymerase enzyme is expressed in the appropriate cells (Elroy-Stein and Moss, 1990 *Proc. Natl. Acad. Sci. USA*, 87, 6743-7; Gao and Huang 1993 *Nucleic Acids Res.*, 21 2867-72; Lieber et al., 1993 *Methods Enzymol.*, 217, 47-66; Zhou et al., 1990 *Mol. Cell. Biol.*, 10, 4529-37). Several investigators have demonstrated that ribozymes expressed from such promoters can function in mammalian cells (e.g. Kashani-Sabet et al., 1992 *Antisense Res. Dev.*, 2, 3-15; Ojwang et al., 1992 *Proc. Natl. Acad. Sci. USA*, 90, 6340-4; L'Huillier et al., 1992 *EMBO J.* 11, 4411-8; Lisiewicz et al., 1993 *Proc. Natl. Acad. Sci. U.S.A.*, 90 8000-4). The above ribozyme transcription units can be incorporated into a variety of vectors for introduction into mammalian cells, including but not restricted to, plasmid DNA vectors, viral DNA vectors

(such as adenovirus or adeno-associated virus vectors), or viral RNA vectors (such as retroviral or alphavirus vectors).

Other features and advantages of the invention will be apparent from the following description of the preferred embodiments thereof, and from  
5 the claims.

#### Description Of The Preferred Embodiments

The drawings will first briefly be described.

#### Drawings:

Figure 1 is a diagrammatic representation of the hammerhead  
10 ribozyme domain known in the art. Stem II can be  $\geq 2$  base-pair long.

Figure 2(a) is a diagrammatic representation of the hammerhead  
ribozyme domain known in the art; Figure 2(b) is a diagrammatic  
representation of the hammerhead ribozyme as divided by Uhlenbeck  
(1987, *Nature*, 327, 596-600) into a substrate and enzyme portion; Figure  
15 2(c) is a similar diagram showing the hammerhead divided by Haseloff and  
Gerlach (1988, *Nature*, 334, 585-591) into two portions; and Figure 2(d) is  
a similar diagram showing the hammerhead divided by Jeffries and  
Symons (1989, *Nucl. Acids. Res.*, 17, 1371-1371) into two portions.

Figure 3 is a diagrammatic representation of the general structure of a  
20 hairpin ribozyme. Helix 2 (H2) is provided with a least 4 base pairs (*i.e.*, *n*  
is 1,2,3 or 4) and helix 5 can be optionally provided of length 2 or more  
bases (preferably 3-20 bases, *i.e.*, *m* is from 1-20 or more). Helix 2 and  
helix 5 may be covalently linked by one or more bases (*i.e.*, *r* is  $\geq 1$  base).  
Helix 1, 4 or 5 may also be extended by 2 or more base pairs (*e.g.*, 4-20  
25 base pairs) to stabilize the ribozyme structure, and preferably is a protein  
binding site. In each instance, each N and N' independently is any normal  
or modified base and each dash represents a potential base-pairing  
interaction. These nucleotides may be modified at the sugar, base or  
phosphate. Complete base-pairing is not required in the helices, but is  
30 preferred. Helix 1 and 4 can be of any size (*i.e.*, *o* and *p* is each  
independently from 0 to any number, *e.g.* 20) as long as some base-pairing  
is maintained. Essential bases are shown as specific bases in the  
structure, but those in the art will recognize that one or more may be

modified chemically (abasic, base, sugar and/or phosphate modifications) or replaced with another base without significant effect. Helix 4 can be formed from two separate molecules, *i.e.*, without a connecting loop. The connecting loop when present may be a ribonucleotide with or without  
5 modifications to its base, sugar or phosphate. "q" is  $\geq 2$  bases. The connecting loop can also be replaced with a non-nucleotide linker molecule. H refers to bases A, U, or C. Y refers to pyrimidine bases. "\_\_\_\_" refers to a covalent bond.

Figure 4 is a representation of the general structure of the hepatitis  
10 delta virus ribozyme domain known in the art.

Figure 5 is a representation of the general structure of the self-cleaving VS RNA ribozyme domain.

Figure 6 is a diagrammatic representation of the genetic map of RSV strain A2.

15 Figure 7 is a diagrammatic representation of the solid-phase synthesis of RNA.

Figure 8 is a diagrammatic representation of exocyclic amino protecting groups for nucleic acid synthesis.

Figure 9 is a diagrammatic representation of the deprotection of RNA.

20 Figure 10 is a graphical representation of the cleavage of an RNA substrate by ribozymes synthesized, deprotected and purified using the improved methods described herein.

Figure 11 is a schematic representation of a two pot deprotection protocol. Base deprotection is carried out with aqueous methyl amine at 65  
25 °C for 10 min. The sample is dried in a speed-vac for 2-24 hours depending on the scale of RNA synthesis. Silyl protecting group at the 2'-hydroxyl position is removed by treating the sample with 1.4 M anhydrous HF at 65°C for 1.5 hours.

Figure 12 is a schematic representation of a one pot deprotection of  
30 RNA synthesized using RNA phosphoramidite chemistry. Anhydrous methyl amine is used to deprotect bases at 65°C for 15 min. The sample is allowed to cool for 10 min before adding TEA•3HF reagent, to the same



pot, to remove protecting groups at the 2'-hydroxyl position. The deprotection is carried out for 1.5 hours.

Figs. 13a - b is a HPLC profile of a 36 nt long ribozyme, targeted to site B. The RNA is deprotected using either the two pot or the one pot deprotection protocol. The peaks corresponding to full-length RNA is indicated. The sequence for site B is CCUGGGCCAGGGAUUA AUGGAGAUGCCCACU.

Figure 14 is a graph comparing RNA cleavage activity of ribozymes deprotected by two pot vs one pot deprotection protocols.

Figure 15 is a schematic representation of an improved method of synthesizing RNA containing phosphorothioate linkages.

Figure 16 shows RNA cleavage reaction catalyzed by ribozymes containing phosphorothioate linkages. Hammerhead ribozyme targeted to site C is synthesized such that 4 nts at the 5' end contain phosphorothioate linkages. P=O refers to ribozyme without phosphorothioate linkages. P=S refers to ribozyme with phosphorothioate linkages. The sequence for site C is UCAUUUUGGCCAUCUC UCCUUCAGGCGUGG.

Figure 17 is a schematic representation of synthesis of 2'-N-phtalimido-nucleoside phosphoramidite.

Figure 18 is a diagrammatic representation of a prior art method for the solid-phase synthesis of RNA using silyl ethers, and the method of this invention using SEM as a 2'-protecting group.

Figure 19 is a diagrammatic representation of the synthesis of 2'-SEM-protected nucleosides and phosphoramidites useful for the synthesis of RNA. B is any nucleotide base as exemplified in the Figure, P is purine and I is inosine. Standard abbreviations are used throughout this application, well known to those in the art.

Figure 20 is a diagrammatic representation of a prior art method for deprotection of RNA using TBDMS protection of the 2'-hydroxyl group.

Figure 21 is a diagrammatic representation of the deprotection of RNA having SEM protection of the 2'-hydroxyl group.

Figure 22 is a representation of an HPLC chromatogram of a fully deprotected 10-mer of uridylic acid.

Figs. 23 - 25 are diagrammatic representations of hammerhead, hairpin or hepatitis delta virus ribozyme containing self-processing RNA transcript. Solid arrows indicate self-processing sites. Boxes indicate the sites of nucleotide substitution. Solid lines are drawn to show the binding sites of primers used in a primer-extension assay. Lower case letters indicate vector sequence present in the RNA when transcribed from a *HindIII*-linearized plasmid. (23) HH Cassette, transcript containing the hammerhead trans-acting ribozyme linked to a 3' cis-acting hammerhead ribozyme. The structure of the hammerhead ribozyme is based on phylogenetic and mutational analysis (reviewed by Symons, 1992 *supra*). The trans ribozyme domain extends from nucleotide 1 through 49. After 3'-end processing, the trans-ribozyme contains 2 non-ribozyme nucleotides (UC at positions 50 and 51) at its 3' end. The 3' processing ribozyme is comprised of nucleotides 44 through 96. Roman numerals I, II and III, indicate the three helices that contribute to the structure of the 3' cis-acting hammerhead ribozyme (Hertel et al., 1992 *Nucleic Acids Res.* 20, 3252). Substitution of G70 and A71 to U and G respectively, inactivates the hammerhead ribozyme (Ruffner et al., 1990 *Biochemistry* 29, 10695) and generates the HH(mutant) construct. (24) HP Cassette, transcript containing the hammerhead trans-acting ribozyme linked to a 3' cis-acting hairpin ribozyme. The structure of the hairpin ribozyme is based on phylogenetic and mutational analysis (Berzal-Herranz et al., 1993 *EMBO J.* 12, 2567). The trans-ribozyme domain extends from nucleotide 1 through 49. After 3'-end processing, the trans-ribozyme contains 5 non-ribozyme nucleotides (UGGCA at positions 50 to 54) at its 3' end. The 3' cis-acting ribozyme is comprised of nucleotides 50 through 115. The transcript named HP(GU) was constructed with a potential wobble base pair between G52 and U77; HP(GC) has a Watson-Crick base pair between G52 and C77. A shortened helix 1 (5 base pairs) and a stable tetraloop (GAAA) at the end of helix 1 was used to connect the substrate with the catalytic domain of the hairpin ribozyme (Feldstein & Bruening, 1993 *Nucleic Acids Res.* 21, 1991; Altschuler et al., 1992 *supra*). (25) HDV Cassette, transcript containing the trans-acting hammerhead ribozyme linked to a 3' cis-acting hepatitis delta virus (HDV) ribozyme. The secondary structure of the HDV ribozyme is as proposed by Been and

coworkers (Been et al., 1992 Biochemistry 31, 11843). The trans-ribozyme domain extends from nucleotides 1 through 48. After 3'-end processing, the trans-ribozyme contains 2 non-ribozyme nucleotides (AA at positions 49 to 50) at its 3' end. The 3' cis-acting HDV ribozyme is comprised of nucleotides 50 through 114. Roman numerals I, II, III & IV, indicate the location of four helices within the 3' cis-acting HDV ribozyme (Perrota & Been, 1991 Nature 350, 434). The  $\Delta$ HDV transcript contains a 31 nucleotide deletion in the HDV portion of the transcript (nucleotides 84 through 115 deleted).

Fig. 26 is a schematic representation of a plasmid containing the insert encoding self-processing cassette. The figure is not drawn to scale.

Fig. 27 demonstrates the effect of 3' flanking sequences on RNA self-processing *in vitro*. H, Plasmid templates linearized with *Hind*III restriction enzyme. Transcripts from H templates contain four non-ribozyme nucleotides at the 3' end. N, Plasmid templates linearized with *Nde*I restriction enzyme. Transcripts from N templates contain 220 non-ribozyme nucleotides at the 3' end. R, Plasmid templates linearized with *Rca*I restriction enzyme. Transcripts from R templates contain 450 non-ribozyme nucleotides at the 3' end.

Fig. 28 shows the effect of 3' flanking sequences on the trans-cleavage reaction catalyzed by a hammerhead ribozyme. A 622 nt internally-labeled RNA (<10 nM) was incubated with ribozyme (1000 nM) under single turn-over conditions (Herschlag and Cech, 1990 Biochemistry 29, 10159). HH+2, HH+37, and HH+52 are trans-acting ribozymes produced by transcription from the HH,  $\Delta$ HDV, and HH(mutant) constructs, respectively, and that contain 2, 37 and 52 extra nucleotides on the 3' end. The plot of the fraction of uncleaved substrate versus time was fit to a double exponential curve using the KaleidaGraph graphing program (Synergy Software, Reading, PA). A double exponential curve fit was used because the data points did not fall on a single exponential curve, presumably due to varying conformers of ribozyme and/or substrate RNA.

Fig. 29 shows RNA self-processing in OST7-1 cells. *In vitro* lanes contain full-length, unprocessed transcripts that were added to cellular lysates prior to RNA extraction. These RNAs were either pre-incubated with  $MgCl_2$  (+) or with DEPC-treated water (-) prior to being hybridized

with 5' end-labeled primers. Cellular lanes contain total cellular RNA from cells transfected with one of the four self-processing constructs. Cellular RNA are probed for ribozyme expression using a sequence specific primer-extension assay. Solid arrows indicate the location of primer extension bands corresponding to Full-Length RNA and 3' Cleavage Products.

Figs. 30,31 are diagrammatic representations of self-processing cassettes that will release trans-acting ribozymes with defined, stable stem-loop structures at the 5' and the 3' end following self-processing. 30, shows various permutations of a hammerhead self-processing cassette. 31, shows various permutations of a hairpin self-processing cassette.

Figs. 32a-b Schematic representation of RNA polymerase III promoter structure. Arrow indicates the transcription start site and the direction of coding region. A, B and C, refer to consensus A, B and C box promoter sequences. I, refers to intermediate cis-acting promoter sequence. PSE, refers to proximal sequence element. DSE, refers to distal sequence element. ATF, refers to activating transcription factor binding element. ?, refers to cis-acting sequence element that has not been fully characterized. EBER, Epstein-Barr-virus-encoded-RNA. TATA is a box well known in the art.

Figs. 33a-e Sequence of the primary tRNA<sup>i</sup><sub>met</sub> and Δ3-5 transcripts. The A and B box are internal promoter regions necessary for pol III transcription. Arrows indicate the sites of endogenous tRNA processing. The Δ3-5 transcript is a truncated version of tRNA wherein the sequence 3' of B box has been deleted (Adeniyi-Jones et al., 1984 *supra*). This modification renders the Δ 3-5 RNA resistant to endogenous tRNA processing.

Figure 34. Schematic representation of RNA structural motifs inserted into the Δ3-5 RNA. Δ3-5/HHI- a hammerhead (HHI) ribozyme was cloned at the 3' region of Δ3-5 RNA; S3- a stable stem-loop structure was incorporated at the 3' end of the Δ3-5/HHI chimera; S5- stable stem-loop structures were incorporated at the 5' and the 3' ends of Δ3-5/HHI ribozyme chimera; S35- sequence at the 3' end of the Δ3-5/HHI ribozyme chimera was altered to enable duplex formation between the 5' end and a complementary 3' region of the same RNA; S35Plus- in addition to structural alterations of S35, sequences were altered to facilitate additional

duplex formation within the non-ribozyme sequence of the  $\Delta 3$ -5/HHI chimera.

Figures 35 and 36. Northern analysis to quantitate ribozyme expression in T cell lines transduced with  $\Delta 3$ -5 vectors. 35)  $\Delta 3$ -5/HHI and its variants were cloned individually into the DC retroviral vector (Sullenger et al., 1990 *supra*). Northern analysis of ribozyme chimeras expressed in MT-2 cells was performed. Total RNA was isolated from cells (Chomczynski & Sacchi, 1987 *Analytical Biochemistry* 162, 156-159), and transduced with various constructs described in Fig. 34. Northern analysis was carried out using standard protocols (*Curr. Protocols Mol. Biol.* 1992, ed. Ausubel et al., Wiley & Sons, NY). Nomenclature is same as in Figure 34. This assay measures the level of expression from the type 2 pol III promoter. 36) Expression of S35 constructs in MT2 cells. S35 (+ribozyme), S35 construct containing HHI ribozyme. S35 (-ribozyme), S35 construct containing no ribozyme.

Figure 37. Ribozyme activity in total RNA extracted from transduced MT-2 cells. Total RNA was isolated from cells transduced with  $\Delta 3$ -5 constructs described in Figs. 35 and 36. In a standard ribozyme cleavage reaction, 5  $\mu$ g total RNA and trace amounts of 5' terminus-labeled ribozyme target RNA were denatured separately by heating to 90°C for 2 min in the presence of 50 mM Tris-HCl, pH 7.5 and 10 mM MgCl<sub>2</sub>. RNAs were renatured by cooling the reaction mixture to 37°C for 10-15 min. Cleavage reaction was initiated by mixing the labeled substrate RNA and total cellular RNA at 37°C. The reaction was allowed to proceed for ~ 18h, following which the samples were resolved on a 20 % urea-polyacrylamide gel. Bands were visualized by autoradiography.

Figures 38 and 39. Ribozyme expression and activity levels in S35-transduced clonal CEM cell lines. 38) Northern analysis of S35-transduced clonal CEM cell lines. Standard curve was generated by spiking known concentrations of in vitro transcribed S5 RNA into total cellular RNA isolated from non-transduced CEM cells. Pool, contains RNA from pooled cells transduced with S35 construct. Pool (-G418 for 3 Mo), contains RNA from pooled cells that were initially selected for resistance to G418 and then grown in the absence of G418 for 3 months. Lanes A through N contain RNA from individual clones that were generated from the pooled cells transduced with S35 construct. tRNA<sub>i</sub><sup>met</sup>, refers to the

endogenous tRNA. S35, refers to the position of the ribozyme band. M, marker lane. 39) Activity levels in S35-transduced clonal CEM cell lines. RNA isolation and cleavage reactions were as described in Fig.37. Nomenclature is same as in Figs. 35 and 36 except, S, 5' terminus-labeled substrate RNA. P, 8 nt 5' terminus-labeled ribozyme-mediated RNA cleavage product.

Figures 40 and 41 are proposed secondary structures of S35 and S35 containing a desired RNA (HHI), respectively. The position of HHI ribozyme is indicated in figure 41. Intramolecular stem refers to the stem structure formed due to an intramolecular base-paired interaction between the 3' sequence and the complementary 5' terminus. The length of the stem ranges from 15-16 base-pairs. Location of the A and the B boxes are shown.

Figures 42 and 43 are proposed secondary structures of S35 plus and S35 plus containing HHI ribozyme.

Figures 44, 45, 46 and 47 are the nucleotide base sequences of S35, HHIS35, S35 Plus, and HHIS35 Plus respectively.

Figs. 48a-b is a general formula for pol III RNA of this invention.

Figure 49 is a digrammatic representation of 5T construct. In this construct the desired RNA is located 3' of the intramolecular stem.

Figures 50 and 51 contain proposed secondary structures of 5T construct alone and 5T construct containing a desired RNA (HHI ribozyme) respectively.

Figure 52 is a diagrammatic representation of TRZ-tRNA chimeras. The site of desired RNA insertion is indicated.

Figure 53 shows the general structure of HHITRZ-A ribozyme chimera. A hammerhead ribozyme targeted to site I is inserted into the stem II region of TRZ-tRNA chimera.

Figure 54 shows the general structure of HPITRZ-A ribozyme chimera. A hairpin ribozyme targeted to site I is cloned into the indicated region of TRZ-tRNA chimera.

Figure 55 shows a comparison of RNA cleavage activity of HHITRZ-A, HHITRZ-B and a chemically synthesized HHI hammerhead ribozymes.

Figure 56 shows expression of ribozymes in T cell lines that are stably transduced with viral vectors. M, markers; lane 1, non-transduced CEM cells; lanes 2 and 3, MT2 and CEM cells transduced with retroviral vectors; lanes 4 and 5, MT2 and CEM cells transduced with AAV vectors.

Figs. 57a-b Schematic diagram of adeno-associated virus and adenovirus vectors for ribozyme delivery. Both vectors utilize one or more ribozyme encoding transcription units (RZ) based on RNA polymerase II or RNA polymerase III promoters. A. Diagram of an AAV-based vector containing minimal AAV sequences comprising the inverted terminal repeats (ITR) at each end of the vector genome, an optional selectable marker (Neo) driven by an exogenous promoter (Pro), a ribozyme transcription unit, and sufficient additional sequences (stuffer) to maintain a vector length suitable for efficient packaging. B. Diagram of ribozyme expressing adenovirus vectors containing deletions of one or more wild type adenovirus coding regions (cross-hatched boxes marked as E1, pIX, E3, and E4), and insertion of the ribozyme transcription unit at any or several of those regions of deletions.

Fig. 58 is a graph showing the effect of arm length variation on the activity of ligated hammerhead (HH) ribozymes. Nomenclature 5/5, 6/6, 7/7, 8/8 and so on refers to the number of base-pairs being formed between the ribozyme and the target. For example, 5/8 means that the HH ribozyme forms 5 bp on the 5' side and 8 bp on the 3' side of the cleavage site for a total of 13 bp.  $-\Delta G$  refers to the free energy of binding calculated for base-paired interactions between the ribozyme and the substrate RNA (Turner and Sugimoto, 1988 *Ann. Rev. Biophys. Chem.* 17, 167). RPI A is a HH ribozyme with 6/6 binding arms.

Figs. 59 and 60 and 61 show cleavage of long substrate (622 nt) by ligated HH ribozymes.

Fig. 62 is a diagrammatic representation of a hammerhead ribozyme (HH-H) targeted against a site termed H. Variants of HH-H are also shown that contain either a 2 base-paired stem II (HH-H1 and HH-H2) or a 3 base-paired stem II (HH-H3 and HH-H4).

Figs. 63 and 64 show RNA cleavage activity of HH-I and its variants (see Fig.62). 63) cleavage of matched substrate RNA (15 nt). 64) cleavage of long substrate RNA (613 nt).

5 Figs. 65a-b is a schematic representation of a method of this invention to synthesize a full length hairpin ribozyme. No splint strand is required for ligation but rather the two fragments hybridize together at helix 4 prior to ligation. The only prerequisite is that the 3' fragment is phosphorylated at its 5' end and that the 3' end of the 5' fragment have a hydroxyl group. The hairpin ribozyme is targeted against site J. H1 and H2 are intermolecular  
10 helices formed between the ribozyme and the substrate. H3 and H4 are intramolecular helices formed within the hairpin ribozyme motif. Arrow indicates the cleavage site.

Fig. 66 shows RNA cleavage activity of ligated hairpin ribozymes targeted against site J.

15 Figs. 67a-b is a diagrammatic representation of a Site K Hairpin Ribozyme (HP-K) showing the proposed secondary structure of the hairpin ribozyme •substrate complex as described in the art (Berzal-Herranz *et al.*, 1993 *EMBO. J.*12, 2567). The ribozyme has been assembled from two fragments (bimolecular ribozyme; Chowrira and Burke, 1992 *Nucleic Acids*  
20 *Res.* 20, 2835); #H1 and H2 represent intermolecular helix formation between the ribozyme and the substrate. H3 and H4 represent intramolecular helix formation within the ribozyme (intermolecular helix in the case of bimolecular ribozyme). Left panel (HP-K1) indicates 4 base-paired helix 2 and the right panel (HP-K2) indicates 6 base-paired helix 2.  
25 Arrow indicates the site of RNA cleavage. All the ribozymes discussed herein were chemically synthesized by solid phase synthesis using RNA phosphoramidite chemistry, unless otherwise indicated. Those skilled in the art will recognize that these ribozymes could also be made transcriptionally *in vitro* and *in vivo*.

30 Figure 68 is a graph showing RNA cleavage by hairpin ribozymes targeted to site K. A plot of fraction of the target RNA uncleaved (fraction uncleaved) as a function of time is shown. HP-K2 (6 bp helix 2) cleaves a 422 target RNA to a greater extent than the HP-K1 (4 bp helix 2).



To make internally-labeled substrate RNA for trans-ribozyme cleavage reactions, a 422 nt region (containing hairpin site A) was synthesized by PCR using primers that place the T7 RNA promoter upstream of the amplified sequence. Target RNA was transcribed in a standard transcription buffer in the presence of [ $\alpha$ - $^{32}$ P]CTP (Chowrira & Burke, 1991 *supra*). The reaction mixture was treated with 15 units of ribonuclease-free DNaseI, extracted with phenol followed chloroform:isoamyl alcohol (25:1), precipitated with isopropanol and washed with 70% ethanol. The dried pellet was resuspended in 20  $\mu$ l DEPC-treated water and stored at -20°C.

Unlabeled ribozyme (1 $\mu$ M) and internally labeled 422 nt substrate RNA (<10 nM) were denatured and renatured separately in a standard cleavage buffer (containing 50 mM Tris-HCl pH 7.5 and 10 mM MgCl<sub>2</sub>) by heating to 90°C for 2 min. and slow cooling to 37°C for 10 min. The reaction was initiated by mixing the ribozyme and substrate mixtures and incubating at 37°C. Aliquots of 5  $\mu$ l were taken at regular time intervals, quenched by adding an equal volume of 2X formamide gel loading buffer and frozen on dry ice. The samples were resolved on 5% polyacrylamide sequencing gel and results were quantitatively analyzed by radioanalytic imaging of gels with a PhosphorImager (Molecular Dynamics, Sunnyvale, CA).

Figs. 69a-b is the Site L Hairpin Ribozyme (HP-L) showing proposed secondary structure of the hairpin ribozyme-substrate complex. The ribozyme was assembled from two fragments as described above. The nomenclature is the same as above.

Figure 70 shows RNA cleavage by hairpin ribozymes targeted to site L. A. plot of fraction of the target RNA uncleaved (fraction uncleaved) as a function of time is shown. HP-L2 (6 bp helix 2) cleaves a 2 KB target RNA to a greater extent than the HP-L1 (4 bp helix 2). To make internally-labeled substrate RNA for *trans*-ribozyme cleavage reactions, a 2 kb region (containing hairpin site L) was synthesized by PCR using primers that place the T7 RNA promoter upstream of the amplified sequence. The cleavage reactions were carried out as described above.

Figs. 71a-b shows a Site M Hairpin Ribozyme (HP-M) with the proposed secondary structure of the hairpin ribozyme•substrate complex. The ribozyme was assembled from two fragments as described above.

Figure 72 is a graph showing RNA cleavage by hairpin ribozymes targeted to site M. The ribozymes were tested at both 20°C and at 26°C. To make internally-labeled substrate RNA for trans-ribozyme cleavage reactions, a 1.9 KB region (containing hairpin site M) was synthesized by PCR using primers that place the T7 RNA promoter upstream of the amplified sequence. Cleavage reactions were carried out as described above except that 20°C and at 26°C temperatures were used.

Figs. 73a-d shows various structural modifications of the present invention. A) Hairpin ribozyme lacking helix 5. Nomenclature is same as described under figure 3. B) Hairpin ribozyme lacking helix 4 and helix 5. Helix 4 is replaced by a nucleotide loop wherein q is  $\geq 2$  bases. Nomenclature is same as described under figure 3. C) Hairpin ribozyme lacking helix 5. Helix 4 loop is replaced by a linker 103"L", wherein L is a non-nucleotide linker molecule (Benseler *et al.*, 1993 *J. Am. Chem. Soc.* 115, 8483; Jennings *et al.*, WO 94/13688). Nomenclature is same as described under figure 3. D) Hairpin ribozyme lacking helix 4 and helix 5. Helix 4 is replaced by non-nucleotide linker molecule "L" (Benseler *et al.*, 1993 *supra*; Jennings *et al.*, *supra*). Nomenclature is same as described under figure 3.

Figs. 74a-b shows Hairpin ribozymes containing nucleotide spacer region "s" at the indicated location, wherein s is  $\geq 1$  base. Hairpin ribozymes containing spacer region, can be synthesized as one fragment or can be assembled from multiple fragments. Nomenclature is same as described under figure 3.

Figs. 75a-e shows the structures of the 5'-C-alkyl-modified nucleotides. R<sub>1</sub> is as defined above. R is OH, H, O-protecting group, NH, or any group described by the publications discussed above, and those described below. B is as defined in the Figure or any other equivalent nucleotide base. CE is cyanoethyl, DMT is a standard blocking group. Other abbreviations are standard in the art.

Figure 76 is a diagrammatic representation of the synthesis of 5'-C-alkyl-D-allose nucleosides and their phosphoramidites.

Figure 77 is a diagrammatic representation of the synthesis of 5'-C-alkyl-L-talose nucleosides and their phosphoramidites.

- 5      Figure 78 is a diagrammatic representation of hammerhead ribozymes targeted to site O containing 5'-C-methyl-L-talo modifications at various positions.

Figure 79 shows RNA cleavage activity of HH-O ribozymes. Fraction of target RNA uncleaved as a function of time is shown.

- 10      Figure 80 is a diagrammatic representation of a position numbered hammerhead ribozyme (according to Hertel *et al. Nucleic Acids Res.* 1992, 20, 3252) showing specific substitutions.

- 15      Figs. 81a-j shows the structures of various 2'-alkyl modified nucleotides which exemplify those of this invention. R groups are alkyl groups, Z is a protecting group.

Figure 82 is a diagrammatic representation of the synthesis of 2'-C-allyl uridine and cytidine.

Figure 83 is a diagrammatic representation of the synthesis of 2'-C-methylene and 2'-C-difluoromethylene uridine.

- 20      Figure 84 is a diagrammatic representation of the synthesis of 2'-C-methylene and 2'-C-difluoromethylene cytidine.

Figure 85 is a diagrammatic representation of the synthesis of 2'-C-methylene and 2'-C-difluoromethylene adenosine.

- 25      Figure 86 is a diagrammatic representation of the synthesis of 2'-C-carboxymethylidene uridine, 2'-C-methoxycarboxymethylidene uridine and derivatized amidites thereof. X is CH<sub>3</sub> or alkyl as discussed above, or another substituent.

Figure 87 is a diagrammatic representation of a synthesis of nucleoside 5'-deoxy-5'-difluoromethylphosphonates.

Figure 88 is a diagrammatic representation of the synthesis of nucleoside 5'-deoxy-5'-difluoromethylphosphonate 3'-phosphoramidites, dimers and solid supported dimers.

Figure 89 is a diagrammatic representation of the synthesis of  
5 nucleoside 5'-deoxy-5'-difluoromethylene triphosphates.

Figures 90 and 91 are diagrammatic representations of the synthesis of 3'-deoxy-3'-difluoromethylphosphonates and dimers.

Figure 92 is a schematic representation of synthesizing RNA phosphoramidite of a nucleotide containing a 2'-hydroxyl group  
10 modification of the present invention.

Figs. 93a-b describes a method for deprotection of oligonucleotides containing a 2'-hydroxyl group modification of the present invention.

Figure 94 is a diagrammatic representation of a hammerhead ribozyme targeted to site N. Positions of 2'-hydroxyl group substitution is  
15 indicated.

Figure 95 shows RNA cleavage activity of ribozymes containing a 2'-hydroxyl group modification of the present invention. All RNA, represents hammerhead ribozyme (HHN) with no 2'-hydroxyl group modifications. U7-ala, represents HHN ribozyme containing 2'-NH-alanine modification at the  
20 U7 position. U4/U7-ala, represents HHA containing 2'-NH-alanine modifications at U4 and U7 positions. U4 lys, represents HHA containing 2'-NH-lysine modification at U4 position. U7 lys, represents HHA containing 2'-NH-lysine modification at U7 position. U4/U7-lys, represents HHN containing 2'-NH-lysine modification at U4 and U7 positions.

25 Figures 96 and 97 are schematic representations of synthesizing (solid-phase synthesis) 3' ends of RNA with modification of the present invention. B, refers to either a base, modified base or an H.

Figure 98 and 99 are schematic representations of synthesizing (solid-phase synthesis) 5' ends of RNA with modification of the present  
30 invention. B, refers to either a base, modified base or an H.

Figures 100 and 101 are general schematic representations of the invention.

Fig. 102a-d is a schematic representation of a method of the invention.

Fig. 103 is a graph of the results of the experiment diagrammed in figure 104.

Figure 104 is a diagrammatic representation of a fusion mRNA used  
5 in the experiment diagrammed in Fig. 102.

Figure 105 is a diagrammatic representation of a method for selection of useful ribozymes of this invention.

Figure 106 generally shows R-loop formation, and an R-loop complex. In addition, it indicates the location at which ligands can be  
10 provided to target the R-loop complex to cells using at least three different procedures, such as ligand receptor interaction, lipid or calcium phosphate mediated delivery, or electroporation.

Figure 107 shows a method for use of self-processing ribozymes to generate therapeutic ribozymes of unit length. This method is essentially  
15 described by Draper et al., PCT WO 93/23509.

Figure 108 shows a method of linking ligands like folate, carbohydrate or peptides to R-loop forming RNA.

Ribozymes of this invention block to some extent ICAM-1, IL-5, rel A, TNF- $\alpha$ , p210<sup>bcr-abl</sup>, or RSV genes expression and can be used to treat  
20 diseases or diagnose such diseases. Ribozymes will be delivered to cells in culture and to tissues in animal models. Ribozyme cleavage of ICAM-1, IL-5, rel A, TNF- $\alpha$ , p210<sup>bcr-abl</sup>, or RSV mRNA in these systems may prevent or alleviate disease symptoms or conditions.

#### I. Target sites

25 Targets for useful ribozymes can be determined as disclosed in Draper et al PCT WO93/23509, Sullivan *et al.*, PCT WO94/02595 as well as by Draper et al., PCT/US94/13129 and hereby incorporated by reference herein in totality. Rather than repeat the guidance provided in those documents here, below are provided specific examples of such  
30 methods, not limiting to those in the art. Ribozymes to such targets are designed as described in those applications and synthesized to be tested *in vitro* and *in vivo*, as also described. Such ribozymes can also be

optimized and delivered as described therein. While specific examples to animal and human RNA are provided, those in the art will recognize that the equivalent human RNA targets described can be used as described below. Thus, the same target may be used, but binding arms suitable for  
5 targeting human RNA sequences are present in the ribozyme. Such targets may also be selected as described below.

It must be established that the sites predicted by the computer-based RNA folding algorithm correspond to potential cleavage sites. Hammerhead or hairpin ribozymes are designed that could bind and are  
10 individually analyzed by computer folding (Jaeger et al., 1989 Proc. Natl. Acad. Sci., USA, 86 7706-7710) to assess whether the ribozyme sequences fold into the appropriate secondary structure. Those ribozymes with unfavorable intramolecular interactions between the binding arms and the catalytic core are eliminated from consideration. Varying binding arm  
15 lengths can be chosen to optimize activity. Generally, at least 5 bases on each arm are able to bind to, or otherwise interact with, the target RNA.

mRNA is screened for accessible cleavage sites by the method described generally in Draper et al., PCT WO93/23569 hereby incorporated by reference herein. Briefly, DNA oligonucleotides  
20 representing potential hammerhead or hairpin ribozyme cleavage sites are synthesized. A polymerase chain reaction is used to generate a substrate for T7 RNA polymerase transcription from cDNA clones. Labeled RNA transcripts are synthesized *in vitro* from DNA templates. The oligonucleotides and the labeled transcripts are annealed, RNaseH is  
25 added and the mixtures are incubated for the designated times at 37°C. Reactions are stopped and RNA separated on sequencing polyacrylamide gels. The percentage of the substrate cleaved is determined by autoradiographic quantitation using a phosphor imaging system. From these data, hammerhead or hairpin ribozyme sites are chosen as the  
30 most accessible.

Ribozymes of the hammerhead or hairpin motif are designed to anneal to various sites in the mRNA message. The binding arms are complementary to the target site sequences described above. The ribozymes are chemically synthesized. The method of synthesis used  
35 follows the procedure for normal RNA synthesis as described in Usman et al., 1987 *J. Am. Chem. Soc.*, 109, 7845 and in Scaringe et al., 1990

*Nucleic Acids Res.*, 18, 5433 and made use of common nucleic acid protecting and coupling groups, such as dimethoxytrityl at the 5'-end, phosphoramidites at the 3'-end. The average stepwise coupling yields are >98%. Inactive ribozymes are synthesized by substituting a U for G5 and a U for A<sub>14</sub> (numbering from Hertel et al., 1992 *Nucleic Acids Res.*, 20, 3252). Hairpin ribozymes are synthesized in two parts and annealed to reconstruct the active ribozyme (Chowrira and Burke, 1992 *Nucleic Acids Res.*, 20, 2835-2840). Ribozymes are also synthesized from DNA templates using bacteriophage T7 RNA polymerase (Milligan and Uhlenbach, 1989, *Methods Enzymol*, 180, 51). All ribozymes are modified extensively to enhance stability by modification with nuclease resistant groups, for example, 2'-amino, 2'-C-allyl, 2'-fluoro, 2'-O-methyl, 2'-H (for a review see Usman and Cedergren, 1992 *TIBS* 17,34). Ribozymes are purified by gel electrophoresis using general methods or are purified by high pressure liquid chromatography and are resuspended in water.

#### Example 1: ICAM-1

Ribozymes that cleave ICAM-1 mRNA represent a novel therapeutic approach to inflammatory or autoimmune disorders. ICAM-1 function can be blocked therapeutically using monoclonal antibodies. Ribozymes have the advantage of being generally immunologically inert, whereas significant neutralizing anti-IgG responses can be observed with some monoclonal antibody treatments.

The following is a brief description of the physiological role of ICAM-1. The discussion is not meant to be complete and is provided only for understanding of the invention that follows. This summary is not an admission that any of the work described below is prior art to the claimed invention.

Intercellular adhesion molecule-1 (ICAM-1) is a cell surface protein whose expression is induced by inflammatory mediators. ICAM-1 is required for adhesion of leukocytes to endothelial cells and for several immunological functions including antigen presentation, immunoglobulin production and cytotoxic cell activity. Blocking ICAM-1 function prevents immune cell recognition and activity during transplant rejection and in animal models of rheumatoid arthritis, asthma and reperfusion injury.

- Cell-cell adhesion plays a pivotal role in inflammatory and immune responses (Springer et al., 1987 *Ann. Rev. Immunol.* 5, 223-252). Cell adhesion is required for leukocytes to bind to and migrate through vascular endothelial cells. In addition, cell-cell adhesion is required for antigen presentation to T cells, for B cell induction by T cells, as well as for the cytotoxicity activity of T cells, NK cells, monocytes or granulocytes. Intercellular adhesion molecule-1 (ICAM-1) is a 110 kilodalton member of the immunoglobulin superfamily that is involved in all of these cell-cell interactions (Simmons et al., 1988 *Nature (London)* 331, 624-627).
- 10 ICAM-1 is expressed on only a limited number of cells and at low levels in the absence of stimulation (Dustin et al., 1986 *J. Immunol.* 137, 245-254). Upon treatment with a number of inflammatory mediators (lipopolysaccharide,  $\gamma$ -interferon, tumor necrosis factor- $\alpha$ , or interleukin-1), a variety of cell types (endothelial, epithelial, fibroblastic and hematopoietic cells) in a variety of tissues express high levels of ICAM-1 on their surface (Springer et al. *supra*; Dustin et al., *supra*; and Rothlein et al., 1988 *J. Immunol.* 141, 1665-1669). Induction occurs via increased transcription of ICAM-1 mRNA (Simmons et al., *supra*). Elevated expression is detectable after 4 hours and peaks after 16 - 24 hours of induction.
- 20 ICAM-1 induction is critical for a number of inflammatory and immune responses. *In vitro*, antibodies to ICAM-1 block adhesion of leukocytes to cytokine-activated endothelial cells (Boyd, 1988 *Proc. Natl. Acad. Sci. USA* 85, 3095-3099; Dustin and Springer, 1988 *J. Cell Biol.* 107, 321-331). Thus, ICAM-1 expression may be required for the extravasation of immune cells to sites of inflammation. Antibodies to ICAM-1 also block T cell killing, mixed lymphocyte reactions, and T cell-mediated B cell differentiation, suggesting that ICAM-1 is required for these cognate cell interactions (Boyd et al., *supra*). The importance of ICAM-1 in antigen presentation is underscored by the inability of ICAM-1 defective murine B cell mutants to stimulate antigen-dependent T cell proliferation (Dang et al., 1990 *J. Immunol.* 144, 4082-4091). Conversely, murine L cells require transfection with human ICAM-1 in addition to HLA-DR in order to present antigen to human T cells (Altmann et al., 1989 *Nature (London)* 338, 512-514). In summary, evidence *in vitro* indicates that ICAM-1 is required for cell-cell interactions critical to inflammatory responses, cellular immune responses, and humoral antibody responses.
- 35



By engineering ribozyme motifs we have designed several ribozymes directed against ICAM-1 mRNA sequences. These have been synthesized with modifications that improve their nuclease resistance. These ribozymes cleave ICAM-1 target sequences *in vitro*.

- 5       The sequence of human, rat and mouse ICAM-1 mRNA can be screened for accessible sites using a computer folding algorithm. Regions of the mRNA that did not form secondary folding structures and that contain potential hammerhead or hairpin ribozyme cleavage sites can be identified. These sites are shown in Tables 2, 3, and 6-9. (All sequences  
10       are 5' to 3' in the tables) While rat, mouse and human sequences can be screened and ribozymes thereafter designed, the human targeted sequences are of most utility.

- 15       The sequences of the chemically synthesized ribozymes useful in this study are shown in Tables 4 - 8 and 10. Those in the art will recognize that these sequences are representative only of many more such sequences where the enzymatic portion of the ribozyme (all but the binding arms) is altered to affect activity and may be formed of ribonucleotides or other nucleotides or non-nucleotides. Such ribozymes are equivalent to the ribozymes described specifically in the Tables.

- 20       The ribozymes will be tested for function *in vivo* by exogenous delivery to human umbilical vein endothelial cells (HUVEC). Ribozymes will be delivered by incorporation into liposomes, by complexing with cationic lipids, by microinjection, or by expression from DNA or RNA vectors described above. Cytokine-induced ICAM-1 expression will be  
25       monitored by ELISA, by indirect immunofluorescence, and/or by FACS analysis. ICAM-1 mRNA levels will be assessed by Northern, by RNase protection, by primer extension or by quantitative RT-PCR analysis. Ribozymes that block the induction of ICAM-1 protein and mRNA by more than 90% will be identified.

- 30       As disclosed by Sullivan et al., PCT WO94/02595, incorporated by reference herein, ribozymes and/or genes encoding them will be locally delivered to transplant tissue *ex vivo* in animal models. Expression of the ribozyme will be monitored by its ability to block *ex vivo* induction of ICAM-1 mRNA and protein. The effect of the anti-ICAM-1 ribozymes on graft  
35       rejection will then be assessed. Similarly, ribozymes will be introduced

into joints of mice with collagen-induced arthritis or rabbits with *Streptococcal* cell wall-induced arthritis. Liposome delivery, cationic lipid delivery, or adeno-associated virus vector delivery can be used. One dose (or a few infrequent doses) of a stable anti-ICAM-1 ribozyme or a gene  
5 construct that constitutively expresses the ribozyme may abrogate inflammatory and immune responses in these diseases.

#### Uses

ICAM-1 plays a central role in immune cell recognition and function. Ribozyme inhibition of ICAM-1 expression can reduce transplant rejection  
10 and alleviate symptoms in patients with rheumatoid arthritis, asthma or other acute and chronic inflammatory disorders. We have engineered several ribozymes that cleave ICAM-1 mRNA. Ribozymes that efficiently inhibit ICAM-1 expression in cells can be readily found and their activity measured with regard to their ability to block transplant rejection and  
15 arthritis symptoms in animal models. These anti-ICAM-1 ribozymes represent a novel therapeutic for the treatment of immunological or inflammatory disorders.

The therapeutic utility of reduction of activity of ICAM-1 function is evident in the following disease targets. The noted references indicate the  
20 role of ICAM-1 and the therapeutic potential of ribozymes described herein. Thus, these targets can be therapeutically treated with agents that reduce ICAM-1 expression or function. These diseases and the studies that support a critical role for ICAM-1 in their pathology are listed below. This list is not meant to be complete and those in the art will recognize further  
25 conditions and diseases that can be effectively treated using ribozymes of the present invention.

- Transplant rejection

ICAM-1 is expressed on venules and capillaries of human cardiac biopsies with histological evidence of graft rejection (Briscoe et al., 1991 *Transplantation*  
30 51, 537-539).

Antibody to ICAM-1 blocks renal (Cosimi et al., 1990 *J. Immunol.* 144, 4604-4612) and cardiac (Flavin et al., 1991 *Transplant. Proc.* 23, 533-534) graft rejection in primates.

A Phase I clinical trial of a monoclonal anti-ICAM-1 antibody showed significant reduction in rejection and a significant increase in graft function in human kidney transplant patients (Haug, et al., 1993 *Transplantation* 55, 766-72).

- Rheumatoid arthritis

- 5 ICAM-1 overexpression is seen on synovial fibroblasts, endothelial cells, macrophages, and some lymphocytes (Chin et al., 1990 *Arthritis Rheum* 33, 1776-86; Koch et al., 1991 *Lab Invest* 64, 313-20).

Soluble ICAM-1 levels correlate with disease severity (Mason et al., 1993 *Arthritis Rheum* 36, 519-27).

- 10 Anti-ICAM antibody inhibits collagen-induced arthritis in mice (Kakimoto et al., 1992 *Cell Immunol* 142, 326-37).

Anti-ICAM antibody inhibits adjuvant-induced arthritis in rats (Iigo et al., 1991 *J Immunol* 147, 4167-71).

- Myocardial ischemia, stroke, and reperfusion injury

- 15 Anti-ICAM-1 antibody blocks adherence of neutrophils to anoxic endothelial cells (Yoshida et al., 1992 *Am J Physiol* 262, H1891-8).

Anti-ICAM-1 antibody reduces neurological damage in a rabbit model of cerebral stroke (Bowes et al., 1993 *Exp Neurol* 119, 215-9).

- 20 Anti-ICAM-1 antibody protects against reperfusion injury in a cat model of myocardial ischemia (Ma et al., 1992 *Circulation* 86, 937-46).

- Asthma

Antibody to ICAM-1 partially blocks eosinophil adhesion to endothelial cells and is overexpressed on inflamed airway endothelium and epithelium *in vivo* (Wegner et al., 1990 *Science* 247, 456-9).

- 25 In a primate model of asthma, anti-ICAM-1 antibody blocks airway eosinophilia (Wegner et al., *supra*) and prevents the resurgence of airway inflammation and hyper-responsiveness after dexamethosone treatment (Gundel et al., 1992 *Clin Exp Allergy* 22, 569-75).

- Psoriasis

Surface ICAM-1 and a clipped, soluble version of ICAM-1 is expressed in psoriatic lesions and expression correlates with inflammation (Kellner et al., 1991 *Br J Dermatol* 125, 211-6; Griffiths 1989 *J Am Acad Dermatol* 20, 617-29; Schopf et al., 1993 *Br J Dermatol* 128, 34-7).

- 5 Anti-ICAM antibody blocks keratinocyte antigen presentation to T cells (Nickoloff et al., 1993 *J Immunol* 150, 2148-59 ).

- Kawasaki disease

Surface ICAM-1 expression correlates with the disease and is reduced by effective immunoglobulin treatment (Leung, et al., 1989 *Lancet* 2, 1298-302).

- 10 Soluble ICAM levels are elevated in Kawasaki disease patients; particularly high levels are observed in patients with coronary artery lesions (Furukawa et al., 1992 *Arthritis Rheum* 35, 672-7; Tsuji, 1992 *Arerugi* 41, 1507-14).

- 15 Circulating LFA-1<sup>+</sup> T cells are depleted (presumably due to ICAM-1 mediated extravasation) in Kawasaki disease patients (Furukawa et al., 1993 *Scand J Immunol* 37, 377-80).

#### Example 2: IL-5

- 20 Ribozymes that cleave IL-5 mRNA represent a novel therapeutic approach to inflammatory disorders like asthma. The invention features use of ribozymes to treat chronic asthma, e.g., by inhibiting the synthesis of IL-5 in lymphocytes and preventing the recruitment and activation of eosinophils.

- 25 A number of cytokines besides IL-5 may also be involved in the activation of inflammation in asthmatic patients, including platelet activating factor, IL-1, IL-3, IL-4, GM-CSF, TNF- $\alpha$ , gamma interferon, VCAM, ILAM-1, ELAM-1 and NF- $\kappa$ B. In addition to these molecules, it is appreciated that any cellular receptors which mediate the activities of the cytokines are also good targets for intervention in inflammatory diseases. These targets include, but are not limited to, the IL-1R and TNF- $\alpha$ R on keratinocytes, epithelial and endothelial cells in airways. Recent data suggest that certain
- 30 neuropeptides may play a role in asthmatic symptoms. These peptides include substance P, neurokinin A and calcitonin-gene-related peptides. These target genes may have more general roles in inflammatory diseases, but are currently assumed to have a role only in asthma.

Ribozymes of this invention block to some extent IL-5 expression and can be used to treat disease or diagnose such disease. Ribozymes will be delivered to cells in culture and to cells or tissues in animal models of asthma (Clutterbuck et al., 1989 supra; Garssen et al., 1991 Am. Rev. Respir. Dis. 144, 931-938; Larsen et al., 1992 J. Clin. Invest. 89, 747-752; Mauser et al., 1993 supra). Ribozyme cleavage of IL-5 mRNA in these systems may prevent inflammatory cell function and alleviate disease symptoms.

The sequence of human and mouse IL-5 mRNA were screened for accessible sites using a computer folding algorithm. Potential hammerhead or hairpin ribozyme cleavage sites were identified. These sites are shown in Tables 11, 13, and 14, 15. (All sequences are 5' to 3' in the tables.) While mouse and human sequences can be screened and ribozymes thereafter designed, the human targeted sequences are of most utility. However, mouse targeted ribozymes are useful to test efficacy of action of the ribozyme prior to testing in humans. The nucleotide base position is noted in the Tables as that site to be cleaved by the designated type of ribozyme. (In Table 12, lower case letters indicate positions that are not conserved between the Human and the Mouse IL-5 sequences.)

The sequences of the chemically synthesized ribozymes useful in this study are shown in Tables 12, 14 - 16. Those in the art will recognize that these sequences are representative only of many more such sequences where the enzymatic portion of the ribozyme (all but the binding arms) is altered to affect activity. For example, stem loop II sequence of hammerhead ribozymes listed in Tables 12 and 14 (5'-GGCCGAAAGGCC-3') can be altered (substitution, deletion and/or insertion) to contain any sequence provided, a minimum of two base-paired stem structure can form. Similarly, stem-loop IV sequence of hairpin ribozymes listed in Tables 15 and 16 (5'-CACGUUGUG-3') can be altered (substitution, deletion and/or insertion) to contain any sequence provided, a minimum of two base-paired stem structure can form. The sequences listed in Tables 12, 14 - 16 may be formed of ribonucleotides or other nucleotides or non-nucleotides. Such ribozymes are equivalent to the ribozymes described specifically in the Tables.

By engineering ribozyme motifs we have designed several ribozymes directed against IL-5 mRNA sequences. These ribozymes are synthesized

with modifications that improve their nuclease resistance. The ability of ribozymes to cleave IL-5 target sequences *in vitro* is evaluated.

The ribozymes will be tested for function *in vivo* by analyzing IL-5 expression levels. Ribozymes will be delivered to cells by incorporation  
5 into liposomes, by complexing with cationic lipids, by microinjection, or by expression from DNA or RNA vectors. IL-5 expression will be monitored by biological assays, ELISA, by indirect immunofluorescence, and/or by FACS analysis. IL-5 mRNA levels will be assessed by Northern analysis, RNAse protection or primer extension analysis or quantitative RT-PCR.  
10 Ribozymes that block the induction of IL-5 activity and/or IL-5 mRNA by more than 90% will be identified.

#### Uses

Interleukin 5 (IL-5), a cytokine produced by CD4+ T helper cells and mast cells, was originally termed B cell growth factor II (reviewed by  
15 Takatsu et al., 1988 Immunol. Rev. 102, 107). It stimulates proliferation of activated B cells and induces production of IgM and IgA. IL-5 plays a major role in eosinophil function by promoting differentiation (Clutterbuck et al., 1989 Blood 73, 1504-12), vascular adhesion (Walsh et al., 1990 Immunology 71, 258-65) and *in vitro* survival of eosinophils (Lopez et al.,  
20 1988 J. Exp. Med. 167, 219-24). This cytokine also enhances histamine release from basophils (Hirai et al., 1990 J. Exp. Med. 172, 1525-8). The following summaries of clinical results support the selection of IL-5 as a primary target for the treatment of asthma:

Several studies have shown a direct correlation between the number  
25 of activated T cells and the number of eosinophils from asthmatic patients vs. normal patients (Oehling et al., 1992 J. Investig. Allergol. Clin. Immunol. 2, 295-9). Patients with either allergic asthma or intrinsic asthma were treated with corticosteroids. The bronchoalveolar lavage was monitored for eosinophils, activated T helper cells and recovery of pulmonary function  
30 over a 28 to 30 day period. The number of eosinophils and activated T helper cells decreased progressively with subsequent improvement in pulmonary function compared to intrinsic asthma patients with no corticosteroid treatment.

Bronchoalveolar lavage cells were screened for production of  
35 cytokines using *in situ* hybridization for mRNA. *In situ* hybridization signals

were detected for IL-2, IL-3, IL-4, IL-5 and GM-CSF. Upregulation of mRNA was observed for IL-4, IL-5 and GM-CSF (Robinson et al., 1993 J. Allergy Clin. Immunol. 92, 313-24). Another study showed that upregulation of IL-5 transcripts from allergen challenged vs. saline challenged asthmatic patients (Krishnaswamy et al., 1993 Am. J. Respir. Cell. Mol. Biol. 9, 279-86).

An 18 patient study was performed to determine a mechanism of action for corticosteroid improvement of asthma symptoms. Improvement was monitored by methacholine responsiveness. A correlation was observed between the methacholine responsiveness, a reduction in the number of eosinophils, a reduction in the number of cells expressing IL-4 and IL-5 mRNA and an increase in number of cells expressing interferon-gamma.

Bronchial biopsies from 15 patients were analyzed 24 hours after allergen challenge (Bentley et al., 1993 Am. J. Respir. Cell. Mol. Biol. 8, 35-42). Increased numbers of eosinophils and IL-2 receptor positive cells were found in the biopsies. No differences in the numbers of total leukocytes, T lymphocytes, elastase-positive neutrophils, macrophages or mast cell subtypes were observed. The number of cells expressing IL-5 and GM-CSF mRNA significantly increased.

In another patient study, the eosinophil phenotype was the same for asthmatic patients and normal individuals. However, eosinophils from asthmatic patients had greater leukotriene C4 producing capacity and migration capacity. There were elevated levels of IL-3, IL-5 and GM-CSF in the circulation of asthmatics but not in normal individuals (Bruijnzeel et al., 1992 Schweiz. Med. Wochenschr. 122, 298-301).

Efficacy of antibody to IL-5 was assessed in a guinea pig asthma model. The animals were challenged with ovalbumin and assayed for eosinophilia and the responsiveness to the bronchioconstriction substance P. A 30 mg/kg dose of antibody administered i.p. blocked ovalbumin-induced increased sensitivity to substance P and blocked increases in bronchoalveolar and lung tissue accumulation of eosinophils (Mauser et al., 1993 Am. Rev. Respir. Dis. 148, 1623-7). In a separate study guinea pigs challenged for eight days with ovalbumin were treated with monoclonal antibody to IL-5. Treatment produced a reduction in the

number of eosinophils in bronchoalveolar lavage. No reduction was observed for unchallenged guinea pigs and guinea pigs treated with a control antibody. Antibody treatment completely inhibited the development of hyperreactivity to histamine and arecoline after ovalbumin challenge  
5 (van Oosterhout et al., 1993 Am. Rev. Respir. Dis. 147, 548-52)

Results obtained from human clinical analysis and animal studies indicate the role of activated T helper cells, cytokines and eosinophils in asthma. The role of IL-5 in eosinophil development and function makes IL-5 a good candidate for target selection. The antibody studies neutralized  
10 IL-5 in the circulation thus preventing eosinophilia. Inhibition of the production of IL-5 will achieve the same goal.

**Asthma** – a prominent feature of asthma is the infiltration of eosinophils and deposition of toxic eosinophil proteins (e.g. major basic protein, eosinophil-derived neurotoxin) in the lung. A number of T-cell-  
15 derived factors like IL-5 are responsible for the activation and maintenance of eosinophils (Kay, 1991 J. Allergy Clin. Immun. 87, 893). Inhibition of IL-5 expression in the lungs can decrease the activation of eosinophils and will help alleviate the symptoms of asthma.

**Atopy** – is characterized by the development of type I hypersensitive  
20 reactions associated with exposure to certain environmental antigens. One of the common clinical manifestations of atopy is eosinophilia (accumulation of abnormally high levels of eosinophils in the blood). Antibodies against IL-5 have been shown to lower the levels of eosinophils in mice (Cook et al., 1993 in Immunopharmacol. Eosinophils ed. Smith and  
25 Cook, pp. 193-216, Academic, London, UK)

**Parasitic infection-related eosinophilia**– infections with parasites like helminths, can lead to severe eosinophilia (Cook et al., 1993 supra). Animal models for eosinophilia suggest that infection of mice, for  
30 example, can lead to blood, peritoneal and/or tissue eosinophilia, all of which seem to be lowered to varying degrees by antibodies directed against IL-5.

**Pulmonary infiltration eosinophilia**– is characterised by accumulation of high levels of eosinophils in pulmonary parenchyma (Gleich, 1990 J. Allergy Clin. Immunol. 85, 422).



**L-Tryptophan-associated eosinophilia-myalgia syndrome**

(EMS)– The EMS disease is closely linked to the consumption of L-tryptophan, an essential aminoacid used to treat conditions like insomnia (for review see Varga et al., 1993 J Invest. Dermatol. 100, 97s). Pathologic and histologic studies have demonstrated high levels of eosinophils and mononuclear inflammatory cells in patients with EMS. It appears that IL-5 and transforming growth factor play a significant role in the development of EMS (Varga et al., 1993 supra) by activating eosinophils and other inflammatory cells.

Thus, ribozymes of the present invention that cleave IL-5 mRNA and thereby IL-5 activity have many potential therapeutic uses, and there are reasonable modes of delivering the ribozymes in a number of the possible indications. Development of an effective ribozyme that inhibits IL-5 function is described above; available cellular and activity assays are numerous, reproducible, and accurate. Animal models for IL-5 function and for each of the suggested disease targets exist (Cook et al., 1993 supra) and can be used to optimize activity.

**Example 3: NF- $\kappa$ B**

Ribozymes that cleave *rel A* mRNA represent a novel therapeutic approach to inflammatory or autoimmune disorders. Inflammatory mediators such as lipopolysaccharide (LPS), interleukin-1 (IL-1) or tumor necrosis factor- $\alpha$  (TNF- $\alpha$ ) act on cells by inducing transcription of a number of secondary mediators, including other cytokines and adhesion molecules. In many cases, this gene activation is known to be mediated by the transcriptional regulator, NF- $\kappa$ B. One subunit of NF- $\kappa$ B, the *relA* gene product (termed RelA or p65) is implicated specifically in the induction of inflammatory responses. Ribozyme therapy, due to its exquisite specificity, is particularly well-suited to target intracellular factors that contribute to disease pathology. Thus, ribozymes that cleave mRNA encoded by *rel A* or TNF- $\alpha$  may represent novel therapeutics for the treatment of inflammatory and autoimmune disorders.

The nuclear DNA-binding activity, NF- $\kappa$ B, was first identified as a factor that binds and activates the immunoglobulin  $\kappa$  light chain enhancer in B cells. NF- $\kappa$ B now is known to activate transcription of a variety of other cellular genes (*e.g.*, cytokines, adhesion proteins, oncogenes and viral

proteins) in response to a variety of stimuli (e.g., phorbol esters, mitogens, cytokines and oxidative stress). In addition, molecular and biochemical characterization of NF- $\kappa$ B has shown that the activity is due to a homodimer or heterodimer of a family of DNA binding subunits. Each subunit bears a stretch of 300 amino acids that is homologous to the oncogene, *v-rel*. The activity first described as NF- $\kappa$ B is a heterodimer of p49 or p50 with p65. The p49 and p50 subunits of NF- $\kappa$ B (encoded by the *nf- $\kappa$ B2* or *nf- $\kappa$ B1* genes, respectively) are generated from the precursors NF- $\kappa$ B1 (p105) or NF- $\kappa$ B2 (p100). The p65 subunit of NF- $\kappa$ B (now termed Rel A) is encoded by the *rel A* locus.

The roles of each specific transcription-activating complex now are being elucidated in cells (N.D. Perkins, et al., 1992 Proc. Natl Acad. Sci USA 89, 1529-1533). For instance, the heterodimer of NF- $\kappa$ B1 and Rel A (p50/p65) activates transcription of the promoter for the adhesion molecule, VCAM-1, while NF- $\kappa$ B2/RelA heterodimers (p49/p65) actually inhibit transcription (H.B. Shu, et al., Mol. Cell. Biol. 13, 6283-6289 (1993)). Conversely, heterodimers of NF- $\kappa$ B2/RelA (p49/p65) act with Tat-I to activate transcription of the HIV genome, while NF- $\kappa$ B1/RelA (p50/p65) heterodimers have little effect (J. Liu, N.D. Perkins, R.M. Schmid, G.J. Nabel, J. Virol. 1992 66, 3883-3887). Similarly, blocking *rel A* gene expression with antisense oligonucleotides specifically blocks embryonic stem cell adhesion; blocking NF- $\kappa$ B1 gene expression with antisense oligonucleotides had no effect on cellular adhesion (Narayanan et al., 1993 Mol. Cell. Biol. 13, 3802-3810). Thus, the promiscuous role initially assigned to NF- $\kappa$ B in transcriptional activation (M.J. Lenardo, D. Baltimore, 1989 Cell 58, 227-229) represents the sum of the activities of the *rel* family of DNA-binding proteins. This conclusion is supported by recent transgenic "knock-out" mice of individual members of the *rel* family. Such "knock-outs" show few developmental defects, suggesting that essential transcriptional activation functions can be performed by more than one member of the *rel* family.

A number of specific inhibitors of NF- $\kappa$ B function in cells exist, including treatment with phosphorothioate antisense oligonucleotide, treatment with double-stranded NF- $\kappa$ B binding sites, and over expression of the natural inhibitor MAD-3 (an I $\kappa$ B family member). These agents have

been used to show that NF- $\kappa$ B is required for induction of a number of molecules involved in inflammation, as described below.

- NF- $\kappa$ B is required for phorbol ester-mediated induction of IL-6 (I. Kitajima, et al., *Science* 258, 1792-5 (1992)) and IL-8 (Kunsch and Rosen, 1993 *Mol. Cell. Biol.* 13, 6137-46).

•NF- $\kappa$ B is required for induction of the adhesion molecules ICAM-1 (Eck, et al., 1993 *Mol. Cell. Biol.* 13, 6530-6536), VCAM-1 (Shu et al., *supra*), and E-selectin (Read, et al., 1994 *J. Exp. Med.* 179, 503-512) on endothelial cells.

- NF- $\kappa$ B is involved in the induction of the integrin subunit, CD18, and other adhesive properties of leukocytes (Eck et al., 1993 *supra*).

The above studies suggest that NF- $\kappa$ B is integrally involved in the induction of cytokines and adhesion molecules by inflammatory mediators. Two recent papers point to another connection between NF- $\kappa$ B and inflammation: glucocorticoids may exert their anti-inflammatory effects by inhibiting NF- $\kappa$ B. The glucocorticoid receptor and p65 both act at NF- $\kappa$ B binding sites in the ICAM-1 promoter (van de Stolpe, et al., 1994 *J. Biol. Chem.* 269, 6185-6192). Glucocorticoid receptor inhibits NF- $\kappa$ B-mediated induction of IL-6 (Ray and Prefontaine, 1994 *Proc. Natl Acad. Sci USA* 91, 752-756). Conversely, overexpression of p65 inhibits glucocorticoid induction of the mouse mammary tumor virus promoter. Finally, protein cross-linking and co-immunoprecipitation experiments demonstrated direct physical interaction between p65 and the glucocorticoid receptor (*Id.*).

Ribozymes of this invention block to some extent NF- $\kappa$ B expression and can be used to treat disease or diagnose such disease. Ribozymes will be delivered to cells in culture and to cells or tissues in animal models of restenosis, transplant rejection and rheumatoid arthritis. Ribozyme cleavage of *relA* mRNA in these systems may prevent inflammatory cell function and alleviate disease symptoms.

The sequence of human and mouse *relA* mRNA can be screened for accessible sites using a computer folding algorithm. Potential hammerhead or hairpin ribozyme cleavage sites were identified. These sites are shown in Tables 17, 18 and 21-22. (All sequences are 5' to 3' in the tables.) While mouse and human sequences can be screened and

ribozymes thereafter designed, the human targetted sequences are of most utility.

5 The sequences of the chemically synthesized ribozymes useful in this study are shown in Tables 19 - 22. Those in the art will recognize that these sequences are representative only of many more such sequences where the enzymatic portion of the ribozyme (all but the binding arms) is altered to affect activity and may be formed of ribonucleotides or other nucleotides or non-nucleotides. Such ribozymes are equivalent to the ribozymes described specifically in the Tables.

10 By engineering ribozyme motifs we have designed several ribozymes directed against *rel A* mRNA sequences. These ribozymes are synthesized with modifications that improve their nuclease resistance. The ability of ribozymes to cleave *rel A* target sequences *in vitro* is evaluated.

15 The ribozymes will be tested for function *in vivo* by analyzing cytokine-induced VCAM-1, ICAM-1, IL-6 and IL-8 expression levels. Ribozymes will be delivered to cells by incorporation into liposomes, by complexing with cationic lipids, by microinjection, or by expression from DNA and RNA vectors. Cytokine-induced VCAM-1, ICAM-1, IL-6 and IL-8 expression will be monitored by ELISA, by indirect immunofluoresence, and/or by FACS  
20 analysis. *Rel A* mRNA levels will be assessed by Northern analysis, RNase protection or primer extension analysis or quantitative RT-PCR. Activity of NF- $\kappa$ B will be monitored by gel-retardation assays. Ribozymes that block the induction of NF- $\kappa$ B activity and/or *rel A* mRNA by more than 50% will be identified.

25 RNA ribozymes and/or genes encoding them will be locally delivered to transplant tissue *ex vivo* in animal models. Expression of the ribozyme will be monitored by its ability to block *ex vivo* induction of VCAM-1, ICAM-1, IL-6 and IL-8 mRNA and protein. The effect of the anti-*rel A* ribozymes on graft rejection will then be assessed. Similarly, ribozymes will be  
30 introduced into joints of mice with collagen-induced arthritis or rabbits with *Streptococcal* cell wall-induced arthritis. Liposome delivery, cationic lipid delivery, or adeno-associated virus vector delivery can be used. One dose (or a few infrequent doses) of a stable anti-*rel A* ribozyme or a gene construct that constitutively expresses the ribozyme may abrogate  
35 inflammatory and immune responses in these diseases.

### Uses

A therapeutic agent that inhibits cytokine gene expression, inhibits adhesion molecule expression, and mimics the anti-inflammatory effects of glucocorticoids (without inducing steroid-responsive genes) is ideal for the treatment of inflammatory and autoimmune disorders. Disease targets for such a drug are numerous. Target indications and the delivery options each entails are summarized below. In all cases, because of the potential immunosuppressive properties of a ribozyme that cleaves *rel A* mRNA, uses are limited to local delivery, acute indications, or *ex vivo* treatment.

#### 10 •Rheumatoid arthritis (RA).

Due to the chronic nature of RA, a gene therapy approach is logical. Delivery of a ribozyme to inflamed joints is mediated by adenovirus, retrovirus, or adeno-associated virus vectors. For instance, the appropriate adenovirus vector can be administered by direct injection into the synovium: high efficiency of gene transfer and expression for several months would be expected (B.J. Roessler, E.D. Allen, J.M. Wilson, J.W. Hartman, B. L. Davidson, J. Clin. Invest. 92, 1085-1092 (1993)). It is unlikely that the course of the disease could be reversed by the transient, local administration of an anti-inflammatory agent. Multiple administrations may be necessary. Retrovirus and adeno-associated virus vectors would lead to permanent gene transfer and expression in the joint. However, permanent expression of a potent anti-inflammatory agent may lead to local immune deficiency.

#### •Restenosis.

25 Expression of NF- $\kappa$ B in the vessel wall of pigs causes a narrowing of the luminal space due to excessive deposition of extracellular matrix components. This phenotype is similar to matrix deposition that occurs subsequent to coronary angioplasty. In addition, NF- $\kappa$ B is required for the expression of the oncogene *c-myc* (F.A. La Rosa, J.W. Pierce, G.E. Sonenshein, Mol. Cell. Biol. 14, 1039-44 (1994)). Thus NF- $\kappa$ B induces smooth muscle proliferation and the expression of excess matrix components: both processes are thought to contribute to reocclusion of vessels after coronary angioplasty.

#### •Transplantation.

NF- $\kappa$ B is required for the induction of adhesion molecules (Eck et al., *supra*, K. O'Brien, et al., J. Clin. Invest. 92, 945-951 (1993)) that function in immune recognition and inflammatory responses. At least two potential modes of treatment are possible. In the first, transplanted organs are treated *ex vivo* with ribozymes or ribozyme expression vectors. Transient inhibition of NF- $\kappa$ B in the transplanted endothelium may be sufficient to prevent transplant-associated vasculitis and may significantly modulate graft rejection. In the second, donor B cells are treated *ex vivo* with ribozymes or ribozyme expression vectors. Recipients would receive the treatment prior to transplant. Treatment of a recipient with B cells that do not express T cell co-stimulatory molecules (such as ICAM-1, VCAM-1, and/or B7 and B7-2) can induce antigen-specific anergy. Tolerance to the donor's histocompatibility antigens could result; potentially, any donor could be used for any transplantation procedure.

15      •Asthma.

Granulocyte macrophage colony stimulating factor (GM-CSF) is thought to play a major role in recruitment of eosinophils and other inflammatory cells during the late phase reaction to asthmatic trauma. Again, blocking the local induction of GM-CSF and other inflammatory mediators is likely to reduce the persistent inflammation observed in chronic asthmatics. Aerosol delivery of ribozymes or adenovirus ribozyme expression vectors is a feasible treatment.

•Gene Therapy.

Immune responses limit the efficacy of many gene transfer techniques. Cells transfected with retrovirus vectors have short lifetimes in immune competent individuals. The length of expression of adenovirus vectors in terminally differentiated cells is longer in neonatal or immune-compromised animals. Insertion of a small ribozyme expression cassette that modulates inflammatory and immune responses into existing adenovirus or retrovirus constructs will greatly enhance their potential.

Thus, ribozymes of the present invention that cleave *rel A* mRNA and thereby NF- $\kappa$ B activity have many potential therapeutic uses, and there are reasonable modes of delivering the ribozymes in a number of the possible indications. Development of an effective ribozyme that inhibits NF- $\kappa$ B

function is described above; available cellular and activity assays are number, reproducible, and accurate. Animal models for NF- $\kappa$ B function (Kitajima, et al., *supra*) and for each of the suggested disease targets exist and can be used to optimize activity.

5 Example 4: TNF- $\alpha$

Ribozymes that cleave the specific sites in TNF- $\alpha$  mRNA represent a novel therapeutic approach to inflammatory or autoimmune disorders.

Tumor necrosis factor- $\alpha$  (TNF- $\alpha$ ) is a protein, secreted by activated leukocytes, that is a potent mediator of inflammatory reactions. Injection of  
10 TNF- $\alpha$  into experimental animals can simulate the symptoms of systemic and local inflammatory diseases such as septic shock or rheumatoid arthritis.

TNF- $\alpha$  was initially described as a factor secreted by activated macrophages which mediates the destruction of solid tumors in mice (Old,  
15 1985 Science 230, 4225-4231). TNF- $\alpha$  subsequently was found to be identical to cachectin, an agent responsible for the weight loss and wasting syndrome associated with tumors and chronic infections (Beutler, et al., 1985 Nature 316, 552-554). The cDNA and the genomic locus for TNF- $\alpha$  have been cloned and found to be related to TNF- $\beta$  (Shakhov et al., 1990  
20 J. Exp. Med. 171, 35-47). Both TNF- $\alpha$  and TNF- $\beta$  bind to the same receptors and have nearly identical biological activities. The two TNF receptors have been found on most cell types examined (Smith, et al., 1990 Science 248, 1019-1023). TNF- $\alpha$  secretion has been detected from monocytes/macrophages, CD4+ and CD8+ T-cells, B-cells, lymphokine  
25 activated killer cells, neutrophils, astrocytes, endothelial cells, smooth muscle cells, as well as various non-hematopoietic tumor cell lines (for a review see Turetskaya et al., 1991 in Tumor Necrosis Factor: Structure, Function, and Mechanism of Action B. B. Aggarwal, J. Vilcek, Eds. Marcel Dekker, Inc., pp. 35-60). TNF- $\alpha$  is regulated transcriptionally and  
30 translationally, and requires proteolytic processing at the plasma membrane in order to be secreted (Kriegler et al., 1988 Cell 53, 45-53). Once secreted, the serum half life of TNF- $\alpha$  is approximately 30 minutes. The tight regulation of TNF- $\alpha$  is important due to the extreme toxicity of this cytokine. Increasing evidence indicates that overproduction of TNF- $\alpha$

during infections can lead to severe systemic toxicity and death (Tracey & Cerami, 1992 Am. J. Trop. Med. Hyg. 47, 2-7).

Antisense RNA and Hammerhead ribozymes have been used in an attempt to lower the expression level of TNF- $\alpha$  by targeting specified cleavage sites [Sioud et al., 1992 J. Mol. Biol. 223; 831; Sioud WO 94/10301; Kisich and co-workers, 1990 abstract (FASEB J. 4, A1860; 1991 slide presentation (J. Leukocyte Biol. sup. 2, 70); December, 1992 poster presentation at Anti-HIV Therapeutics Conference in San Diego, CA; and "Development of anti-TNF- $\alpha$  ribozymes for the control of TNF- $\alpha$  gene expression"- Kisich, Doctoral Dissertation, 1993 University of California, Davis] listing various TNF $\alpha$  targeted ribozymes.

Ribozymes of this invention block to some extent TNF- $\alpha$  expression and can be used to treat disease or diagnose such disease. Ribozymes will be delivered to cells in culture and to cells or tissues in animal models of septic shock and rheumatoid arthritis. Ribozyme cleavage of TNF- $\alpha$  mRNA in these systems may prevent inflammatory cell function and alleviate disease symptoms.

The sequence of human and mouse TNF- $\alpha$  mRNA can be screened for accessible sites using a computer folding algorithm. Hammerhead or hairpin ribozyme cleavage sites were identified. These sites are shown in Tables 23, 25, and 27 - 28. (All sequences are 5' to 3' in the tables.) While mouse and human sequences can be screened and ribozymes thereafter designed, the human targeted sequences are of most utility. However, mouse targeted ribozymes are useful to test efficacy of action of the ribozyme prior to testing in humans. The nucleotide base position is noted in the Tables as that site to be cleaved by the designated type of ribozyme. (In Table 24, lower case letters indicate positions that are not conserved between the human and the mouse TNF- $\alpha$  sequences.)

The sequences of the chemically synthesized ribozymes useful in this study are shown in Tables 24, 26 - 28. Those in the art will recognize that these sequences are representative only of many more such sequences where the enzymatic portion of the ribozyme (all but the binding arms) is altered to affect activity. For example, stem-loop II sequence of hammerhead ribozymes listed in Tables 24 and 26 (5'-GGCCGAAAGGCC-3') can be altered (substitution, deletion, and/or insertion) to contain any



sequences provided a minimum of two base-paired stem structure can form. Similarly, stem-loop IV sequence of hairpin ribozymes listed in Tables 27 and 28 (5'-CACGUUGUG-3') can be altered (substitution, deletion, and/or insertion) to contain any sequence, provided a minimum of two base-paired stem structure can form. The sequences listed in Tables 24, 26 - 28 may be formed of ribonucleotides or other nucleotides or non-nucleotides. Such ribozymes are equivalent to the ribozymes described specifically in the Tables or AAV.

In a preferred embodiment of the invention, a transcription unit expressing a ribozyme that cleaves TNF- $\alpha$  RNA is inserted into a plasmid DNA vector or an adenovirus DNA viral vector or AAV or alpha virus or retrovirus vectors. Viral vectors have been used to transfer genes to the intact vasculature or to joints of live animals (Willard et al., 1992 Circulation, 86, 1-473.; Nabel et al., 1990 Science, 249, 1285-1288) and both vectors lead to transient gene expression. The adenovirus vector is delivered as recombinant adenoviral particles. DNA may be delivered alone or complexed with vehicles (as described for RNA above). The DNA, DNA/vehicle complexes, or the recombinant adenovirus particles are locally administered to the site of treatment, e.g., through the use of an injection catheter, stent or infusion pump or are directly added to cells or tissues *ex vivo*.

In another preferred embodiment of the invention, a transcription unit expressing a ribozyme that cleaves TNF- $\alpha$  RNA is inserted into a retrovirus vector for sustained expression of ribozyme(s).

By engineering ribozyme motifs we have designed several ribozymes directed against TNF- $\alpha$  mRNA sequences. These ribozymes are synthesized with modifications that improve their nuclease resistance. The ability of ribozymes to cleave TNF- $\alpha$  target sequences *in vitro* is evaluated.

The ribozymes will be tested for function in cells by analyzing bacterial lipopolysaccharide (LPS)-induced TNF- $\alpha$  expression levels. Ribozymes will be delivered to cells by incorporation into liposomes, by complexing with cationic lipids, by microinjection, or by expression from DNA vectors. TNF- $\alpha$  expression will be monitored by ELISA, by indirect immunofluorescence, and/or by FACS analysis. TNF- $\alpha$  mRNA levels will be assessed by Northern analysis, RNase protection, primer extension

analysis or quantitative RT-PCR. Ribozymes that block the induction of TNF- $\alpha$  activity and/or TNF- $\alpha$  mRNA by more than 90% will be identified.

RNA ribozymes and/or genes encoding them will be locally delivered to macrophages by intraperitoneal injection. After a period of ribozyme uptake, the peritoneal macrophages are harvested and induced *ex vivo* with LPS. The ribozymes that significantly reduce TNF- $\alpha$  secretion are selected. The TNF- $\alpha$  can also be induced after ribozyme treatment with fixed *Streptococcus* in the peritoneal cavity instead of *ex vivo*. In this fashion the ability of TNF- $\alpha$  ribozymes to block TNF- $\alpha$  secretion in a localized inflammatory response are evaluated. In addition, we will determine if the ribozymes can block an ongoing inflammatory response by delivering the TNF- $\alpha$  ribozymes after induction by the injection of fixed *Streptococcus*.

To examine the effect of anti-TNF- $\alpha$  ribozymes on systemic inflammation, the ribozymes are delivered by intravenous injection. The ability of the ribozymes to inhibit TNF- $\alpha$  secretion and lethal shock caused by systemic LPS administration are assessed. Similarly, TNF- $\alpha$  ribozymes can be introduced into the joints of mice with collagen-induced arthritis. Either free delivery, liposome delivery, cationic lipid delivery, adeno-associated virus vector delivery, adenovirus vector delivery, retrovirus vector delivery or plasmid vector delivery in these animal model experiments can be used to supply ribozymes. One dose (or a few infrequent doses) of a stable anti-TNF- $\alpha$  ribozyme or a gene construct that constitutively expresses the ribozyme may abrogate tissue damage in these inflammatory diseases.

#### *Macrophage isolation.*

To produce responsive macrophages 1 ml of sterile fluid thioglycollate broth (Difco, Detroit, MI.) was injected i.p. into 6 week old female C57b/6NCR mice 3 days before peritoneal lavage. Mice were maintained as specific pathogen free in autoclaved cages in a laminar flow hood and given sterilized water to minimize "spontaneous" activation of macrophages. The resulting peritoneal exudate cells (PEC) were obtained by lavage using Hanks balanced salt solution (HBSS) and were plated at  $2.5 \times 10^5$ /well in 96 well plates (Costar, Cambridge, MA.) with Eagles minimal essential medium (EMEM) containing 10% heat inactivated fetal

bovine serum. After adhering for 2 hours the wells were washed to remove non-adherent cells. The resulting cultures were 97% macrophages as determined by morphology and staining for non-specific esterase.

*Transfection of ribozymes into macrophages:*

- 5       The ribozymes were diluted to 2X final concentration, mixed with an equal volume of 11nM lipofectamine (Life Technologies, Gaithersburg, MD.), and vortexed. 100 ml of lipid:ribozyme complex was then added directly to the cells, followed immediately by 10 ml fetal bovine serum. Three hours after ribozyme addition 100 ml of 1 mg/ml bacterial lipopolysaccharide (LPS) was added to each well to stimulate TNF production.
- 10

*Quantitation of TNF- $\alpha$  in mouse macrophages:*

- Supernatants were sampled at 0, 2, 4, 8, and 24 hours post LPS stimulation and stored at -70°C. Quantitation of TNF- $\alpha$  was done by a specific ELISA. ELISA plates were coated with rabbit anti-mouse TNF- $\alpha$  serum at 1:1000 dilution (Genzyme) followed by blocking with milk proteins and incubation with TNF- $\alpha$  containing supernatants. TNF- $\alpha$  was then detected using a murine TNF- $\alpha$  specific hamster monoclonal antibody (Genzyme). The ELISA was developed with goat anti-hamster IgG coupled to alkaline phosphatase.
- 15
- 20

*Assessment of reagent toxicity:*

- Following ribozyme/lipid treatment of macrophages and harvesting of supernatants viability of the cells was assessed by incubation of the cells with 5 mg/ml of 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl tetrazolium bromide (MTT). This compound is reduced by the mitochondrial dihydrogenases, the activity of which correlates well with cell viability. After 12 hours the absorbance of reduced MTT is measured at 585 nm.
- 25

Uses

- The association between TNF- $\alpha$  and bacterial sepsis, rheumatoid arthritis, and autoimmune disease make TNF- $\alpha$  an attractive target for therapeutic intervention [Tracy & Cerami 1992 supra; Williams et al., 1992 Proc. Natl. Acad. Sci. USA 89, 9784-9788; Jacob, 1992 J. Autoimmun. 5 (Supp. A), 133-143].
- 30

### Septic Shock

Septic shock is a complication of major surgery, bacterial infection, and polytrauma characterized by high fever, increased cardiac output, reduced blood pressure and a neutrophilic infiltrate into the lungs and other major organs. Current treatment options are limited to antibiotics to reduce the bacterial load and non-steroidal anti-inflammatories to reduce fever. Despite these treatments in the best intensive care settings, mortality from septic shock averages 50%, due primarily to multiple organ failure and disseminated vascular coagulation. Septic shock, with an incidence of 200,000 cases per year in the United States, is the major cause of death in intensive care units. In septic shock syndrome, tissue injury or bacterial products initiate massive immune activation, resulting in the secretion of pro-inflammatory cytokines which are not normally detected in the serum, such as TNF- $\alpha$ , interleukin-1 $\beta$  (IL-1 $\beta$ ),  $\gamma$ -interferon (IFN- $\gamma$ ), interleukin-6 (IL-6), and interleukin-8 (IL-8). Other non-cytokine mediators such as leukotriene b<sub>4</sub>, prostaglandin E<sub>2</sub>, C3a and C3d also reach high levels (de Boer et al., 1992 *Immunopharmacology* 24, 135-148).

TNF- $\alpha$  is detected early in the course of septic shock in a large fraction of patients (de Boer et al., 1992 *supra*). In animal models, injection of TNF- $\alpha$  has been shown to induce shock-like symptoms similar to those induced by LPS injection (Beutler et al., 1985 *Science* 229, 869-871); in contrast, injection of IL-1 $\beta$ , IL-6, or IL-8 does not induce shock. Injection of TNF- $\alpha$  also causes an elevation of IL-1 $\beta$ , IL-6, IL-8, PgE<sub>2</sub>, acute phase proteins, and TxA<sub>2</sub> in the serum of experimental animals (de Boer et al., 1992 *supra*). In animal models the lethal effects of LPS can be blocked by pre-administration of anti-TNF- $\alpha$  antibodies. The cumulative evidence indicates that TNF- $\alpha$  is a key player in the pathogenesis of septic shock, and therefore a good candidate for therapeutic intervention.

### Rheumatoid Arthritis

Rheumatoid arthritis (RA) is an autoimmune disease characterized by chronic inflammation of the joints leading to bone destruction and loss of joint function. At the cellular level, autoreactive T- lymphocytes and monocytes are typically present, and the synoviocytes often have altered morphology and immunostaining patterns. RA joints have been shown to contain elevated levels of TNF- $\alpha$ , IL-1 $\alpha$  and IL-1 $\beta$ , IL-6, GM-CSF, and TGF-

β (Abney et al., 1991 Imm. Rev. 119, 105-123), some or all of which may contribute to the pathological course of the disease.

Cells cultured from RA joints spontaneously secrete all of the pro-inflammatory cytokines detected *in vivo*. Addition of antisera against TNF-α to these cultures has been shown to reduce IL-1α/β production by these cells to undetectable levels (Abney et al., 1991 Supra). Thus, TNF-α may directly induce the production of other cytokines in the RA joint. Addition of the anti-inflammatory cytokine, TGF-β, has no effect on cytokine secretion by RA cultures. Immunocytochemical studies of human RA surgical specimens clearly demonstrate the production of TNF-α, IL-1α/β, and IL-6 from macrophages near the cartilage/pannus junction when the pannus is invading and overgrowing the cartilage (Chu et al., 1992 Br. J. Rheumatology 31, 653-661). GM-CSF was shown to be produced mainly by vascular endothelium in these samples. Both TNF-α and TGF-β have been shown to be fibroblast growth factors, and may contribute to the accumulation of scar tissue in the RA joint. TNF-α has also been shown to increase osteoclast activity and bone resorption, and may have a role in the bone erosion commonly found in the RA joint (Cooper et al., 1992 Clin. Exp. Immunol. 89, 244-250).

Elimination of TNF-α from the rheumatic joint would be predicted to reduce overall inflammation by reducing induction of MHC class II, IL-1α/β, IL-6, and GM-CSF, and reducing T-cell activation. Osteoclast activity might also fall, reducing the rate of bone erosion at the joint. Finally, elimination of TNF-α would be expected to reduce accumulation of scar tissue within the joint by removal of a fibroblast growth factor.

Treatment with an anti-TNF-α antibody reduces joint swelling and the histological severity of collagen-induced arthritis in mice (Williams et al., 1992 Proc. Natl. Acad. Sci. USA 89, 9784-9788). In addition, a study of RA patients who have received i.v. infusions of anti-TNF-α monoclonal antibody reports a reduction in the number and severity of inflamed joints after treatment. The benefit of monoclonal antibody treatment in the long term may be limited by the expense and immunogenicity of the antibody.

#### Psoriasis

Psoriasis is an inflammatory disorder of the skin characterized by keratinocyte hyperproliferation and immune cell infiltrate (Kupper, 1990 J.

Clin. Invest. 86, 1783-1789). It is a fairly common condition, affecting 1.5-2.0% of the population. The disorder ranges in severity from mild, with small flaky patches of skin, to severe, involving inflammation of the entire epidermis. The cellular infiltrate of psoriasis includes T-lymphocytes, neutrophils, macrophages, and dermal dendrocytes. The majority of T-lymphocytes are activated CD4<sup>+</sup> cells of the T<sub>H</sub>-1 phenotype, although some CD8<sup>+</sup> and CD4<sup>+</sup>/CD8<sup>+</sup> are also present. B lymphocytes are typically not found in abundance in psoriatic plaques.

Numerous hypotheses have been offered as to the proximal cause of psoriasis including auto-antibodies and auto-reactive T-cells, overproduction of growth factors, and genetic predisposition. Although there is evidence to support the involvement of each of these factors in psoriasis, they are neither mutually exclusive nor are any of them necessary and sufficient for the pathogenesis of psoriasis (Reeves, 1991 Semin. Dermatol. 10, 217).

The role of cytokines in the pathogenesis of psoriasis has been investigated. Among those cytokines found to be abnormally expressed were TGF- $\alpha$ , IL-1 $\alpha$ , IL-1 $\beta$ , IL-1ra, IL-6, IL-8, IFN- $\gamma$ , and TNF- $\alpha$ . In addition to abnormal cytokine production, elevated expression of ICAM-1, ELAM-1, and VCAM has been observed (Reeves, 1991 supra). This cytokine profile is similar to that of normal wound healing, with the notable exception that cytokine levels subside upon healing. Keratinocytes themselves have recently been shown to be capable of secreting EGF, TGF- $\alpha$ , IL-6, and TNF- $\alpha$ , which could increase proliferation in an autocrine fashion (Oxholm et al., 1991 APMIS 99, 58-64).

Nickoloff et al., 1993 (J Dermatol Sci. 6, 127-33) have proposed the following model for the initiation and maintenance of the psoriatic plaque:

Tissue damage induces the wound healing response in the skin. Keratinocytes secrete IL-1 $\alpha$ , IL-1 $\beta$ , IL-6, IL-8, TNF- $\alpha$ . These factors activate the endothelium of dermal capillaries, recruiting PMNs, macrophages, and T-cells into the wound site.

Dermal dendrocytes near the dermal/epidermal junction remain activated when they should return to a quiescent state, and subsequently secrete cytokines including TNF- $\alpha$ , IL-6, and IL-8. Cytokine expression, in

turn, maintains the activated state of the endothelium, allowing extravasation of additional immunocytes, and the activated state of the keratinocytes which secrete TGF- $\alpha$  and IL-8. Keratinocyte IL-8 recruits immunocytes from the dermis into the epidermis. During passage through the dermis, T-cells encounter the activated dermal dendrocytes which efficiently activate the T<sub>H</sub>-1 phenotype. The activated T-cells continue to migrate into the epidermis, where they are stimulated by keratinocyte-expressed ICAM-1 and MHC class II. IFN- $\gamma$  secreted by the T-cells synergizes with the TNF- $\alpha$  from dermal dendrocytes to increase keratinocyte proliferation and the levels of TGF- $\alpha$ , IL-8, and IL-6 production. IFN- $\gamma$  also feeds back to the dermal dendrocyte, maintaining the activated phenotype and the inflammatory cycle.

Elevated serum titres of IL-6 increases synthesis of acute phase proteins including complement factors by the liver, and antibody production by plasma cells. Increased complement and antibody levels increases the probability of autoimmune reactions.

Maintenance of the psoriatic plaque requires continued expression of all of these processes, but attractive points of therapeutic intervention are TNF- $\alpha$  expression by the dermal dendrocyte to maintain activated endothelium and keratinocytes, and IFN- $\gamma$  expression by T-cells to maintain activated dermal dendrocytes.

There are 3 million patients in the United States afflicted with psoriasis. The available treatments for psoriasis are corticosteroids. The most widely prescribed are TEMOVATE (clobetasol propionate), LIDEX (fluocinonide), DIPROLENE (betamethasone propionate), PSORCON (diflorasone diacetate) and TRIAMCINOLONE formulated for topical application. The mechanism of action of corticosteroids is multifactorial. This is a palliative therapy because the underlying cause of the disease remains, and upon discontinuation of the treatment the disease returns. Discontinuation of treatment is often prompted by the appearance of adverse effects such as atrophy, telangiectasias and purpura. Corticosteroids are not recommended for prolonged treatments or when treatment of large and/or inflamed areas is required. Alternative treatments include retinoids, such as etretinate, which has been approved for treatment of severe, refractory psoriasis. Alternative retinoid-based treatments are in advanced clinical trials. Retinoids act by converting

keratinocytes to a differentiated state and restoration of normal skin development. Immunosuppressive drugs such as cyclosporine are also in the advanced stages of clinical trials. Due to the nonspecific mechanism of action of corticosteroids, retinoids and immunosuppressives, these treatments exhibit severe side effects and should not be used for extended periods of time unless the condition is life-threatening or disabling. There is a need for a less toxic, effective therapeutic agent in psoriatic patients.

#### HIV and AIDS

The human immunodeficiency virus (HIV) causes several fundamental changes in the human immune system from the time of infection until the development of full-blown acquired immunodeficiency syndrome (AIDS). These changes include a shift in the ratio of CD4+ to CD8+ T-cells, sustained elevation of IL-4 levels, episodic elevation of TNF- $\alpha$  and TNF- $\beta$  levels, hypergammaglobulinemia, and lymphoma/leukemia (Rosenberg & Fauci, 1990 Immun. Today 11, 176; Weiss 1993 Science 260, 1273). Many patients experience a unique tumor, Kaposi's sarcoma and/or unusual opportunistic infections (e.g. *Pneumocystis carinii*, cytomegalovirus, herpesviruses, hepatitis viruses, papilloma viruses, and tuberculosis). The immunological dysfunction of individuals with AIDS suggests that some of the pathology may be due to cytokine dysregulation.

Levels of serum TNF- $\alpha$  and IL-6 are often found to be elevated in AIDS patients (Weiss, 1993 supra). In tissue culture, HIV infection of monocytes isolated from healthy individuals stimulates secretion of both TNF- $\alpha$  and IL-6. This response has been reproduced using purified gp120, the viral coat protein responsible for binding to CD-4 (Buonaguro et al., 1992 J. Virol. 66, 7159). It has also been demonstrated that the viral gene regulator, Tat, can directly induce TNF transcription. The ability of HIV to directly stimulate secretion of TNF- $\alpha$  and IL-6 may be an adaptive mechanism of the virus. TNF- $\alpha$  has been shown to upregulate transcription of the LTR of HIV, increasing the number of HIV-specific transcripts in infected cells. IL-6 enhances HIV production, but at a post-transcriptional level, apparently increasing the efficiency with which HIV transcripts are translated into protein. Thus, stimulation of TNF- $\alpha$  secretion by the HIV virus may promote infection of neighboring CD4+ cells both by enhancing virus production from latently infected cells and by driving replication of the virus in newly infected cells.



The role of TNF- $\alpha$  in HIV replication has been well established in tissue culture models of infection (Sher et al., 1992 Immun. Rev. 127, 183), suggesting that the mutual induction of HIV replication and TNF- $\alpha$  replication may create positive feedback *in vivo*. However, evidence for the presence of such positive feedback in infected patients is not abundant. TNF- $\alpha$  levels are found to be elevated in some, but not all patients tested. Children with AIDS who were given zidovudine had reduced levels of TNF- $\alpha$  compared to those not given zidovudine (Cremoni et al., 1993 AIDS 7, 128). This correlation lends support to the hypothesis that reduced viral replication is physiologically linked to TNF- $\alpha$  levels. Furthermore, recently it has been shown that the polyclonal B cell activation associated with HIV infection is due to membrane-bound TNF- $\alpha$ . Thus, levels of secreted TNF- $\alpha$  may not accurately reflect the contribution of this cytokine to AIDS pathogenesis.

Chronic elevation of TNF- $\alpha$  has been shown to result in cachexia (Tracey et al., 1992 Am. J. Trop. Med. Hyg. 47, 2-7), increased autoimmune disease (Jacob, 1992 supra), lethargy, and immune suppression in animal models (Aderka et al., 1992 Isr. J. Med. Sci. 28, 126-130). The cachexia associated with AIDS may be associated with chronically elevated TNF- $\alpha$  frequently observed in AIDS patients. Similarly, TNF- $\alpha$  can stimulate the proliferation of spindle cells isolated from Kaposi's sarcoma lesions of AIDS patients (Barillari et al., 1992 J. Immunol 149, 3727).

A therapeutic agent that inhibits cytokine gene expression, inhibits adhesion molecule expression, and mimics the anti-inflammatory effects of glucocorticoids (without inducing steroid-responsive genes) is ideal for the treatment of inflammatory and autoimmune disorders. Disease targets for such a drug are numerous. Target indications and the delivery options each entails are summarized below. In all cases, because of the potential immunosuppressive properties of a ribozyme that cleaves the specified sites in TNF- $\alpha$  mRNA, uses are limited to local delivery, acute indications, or *ex vivo* treatment.

- Septic shock.

Exogenous delivery of ribozymes to macrophages can be achieved by intraperitoneal or intravenous injections. Ribozymes will be delivered by incorporation into liposomes or by complexing with cationic lipids.

•Rheumatoid arthritis (RA).

- 5 Due to the chronic nature of RA, a gene therapy approach is logical. Delivery of a ribozyme to inflamed joints is mediated by adenovirus, retrovirus, or adeno-associated virus vectors. For instance, the appropriate adenovirus vector can be administered by direct injection into the synovium: high efficiency of gene transfer and expression for several
- 10 months would be expected (B.J. Roessler, E.D. Allen, J.M. Wilson, J.W. Hartman, B. L. Davidson, J. Clin. Invest. 92, 1085-1092 (1993)). It is unlikely that the course of the disease could be reversed by the transient, local administration of an anti-inflammatory agent. Multiple administrations may be necessary. Retrovirus and adeno-associated virus
- 15 vectors would lead to permanent gene transfer and expression in the joint. However, permanent expression of a potent anti-inflammatory agent may lead to local immune deficiency.

•Psoriasis

- The psoriatic plaque is a particularly good candidate for ribozyme or
- 20 vector delivery. The stratum comeum of the plaque is thinned, providing access to the proliferating keratinocytes. T-cells and dermal dendrocytes can be efficiently targeted by trans-epidermal diffusion .

- Organ culture systems for biopsy specimens of psoriatic and normal skin are described in current literature (Nickoloff et al., 1993 Supra).
- 25 Primary human keratinocytes are easily obtained and will be grown into epidermal sheets in tissue culture. In addition to these tissue culture models, the flaky skin mouse develops psoriatic skin in response to UV light. This model would allow demonstration of animal efficacy for ribozyme treatments of psoriasis.

- 30 •Gene Therapy.

Immune responses limit the efficacy of many gene transfer techniques. Cells transfected with retrovirus vectors have short lifetimes in immune competent individuals. The length of expression of adenovirus

vectors in terminally differentiated cells is longer in neonatal or immune-compromised animals. Insertion of a small ribozyme expression cassette that modulates inflammatory and immune responses into existing adenovirus or retrovirus constructs will greatly enhance their potential.

5        Thus, ribozymes of the present invention that cleave TNF- $\alpha$  mRNA and thereby TNF- $\alpha$  activity have many potential therapeutic uses, and there are reasonable modes of delivering the ribozymes in a number of the possible indications. Development of an effective ribozyme that inhibits TNF- $\alpha$  function is described above; available cellular and activity assays  
10        are number, reproducible, and accurate. Animal models for TNF- $\alpha$  function and for each of the suggested disease targets exist and can be used to optimize activity.

Example 5: p210<sup>bcr-abl</sup>

15        Chronic myelogenous leukemia exhibits a characteristic disease course, presenting initially as a chronic granulocytic hyperplasia, and invariably evolving into an acute leukemia which is caused by the clonal expansion of a cell with a less differentiated phenotype (i.e., the blast crisis stage of the disease). CML is an unstable disease which ultimately progresses to a terminal stage which resembles acute leukemia. This  
20        lethal disease affects approximately 16,000 patients a year. Chemotherapeutic agents such as hydroxyurea or busulfan can reduce the leukemic burden but do not impact the life expectancy of the patient (e.g., approximately 4 years). Consequently, CML patients are candidates for bone marrow transplantation (BMT) therapy. However, for those patients  
25        which survive BMT, disease recurrence remains a major obstacle (Apperley et al., 1988 Br. J. Haematol. 69, 239).

30        The Philadelphia (Ph) chromosome which results from the translocation of the *abl* oncogene from chromosome 9 to the *bcr* gene on chromosome 22 is found in greater than 95% of CML patients and in 10-25% of all cases of acute lymphoblastic leukemia [(ALL); Fourth International Workshop on Chromosomes in Leukemia 1982, Cancer Genet. Cytogenet. 11, 316]. In virtually all Ph-positive CMLs and approximately 50% of the Ph-positive ALLs, the leukemic cells express *bcr-abl* fusion mRNAs in which exon 2 (b2-a2 junction) or exon 3 (b3-a2  
35        junction) from the major breakpoint cluster region of the *bcr* gene is spliced

to exon 2 of the *abl* gene. Heisterkamp et al., 1985 Nature 315, 758; Shtivelman et al., 1987, Blood 69, 971). In the remaining cases of Ph-positive ALL, the first exon of the *bcr* gene is spliced to exon 2 of the *abl* gene (Hooberman et al., 1989 Proc. Nat. Acad. Sci. USA 86, 4259; 5 Heisterkamp et al., 1988 Nucleic Acids Res. 16, 10069).

The b3-a2 and b2-a2 fusion mRNAs encode 210 kd bcr-abl fusion proteins which exhibit oncogenic activity (Daley et al., 1990 Science 247, 824; Heisterkamp et al., 1990 Nature 344, 251). The importance of the bcr-abl fusion protein (p210<sup>bcr-abl</sup>) in the evolution and maintenance of the 10 leukemic phenotype in human disease has been demonstrated using antisense oligonucleotide inhibition of p210<sup>bcr-abl</sup> expression. These inhibitory molecules have been shown to inhibit the in vitro proliferation of leukemic cells in bone marrow from CML patients. Szczylik et al., 1991 Science 253, 562).

15 Reddy, U.S. Patent 5,246,921 (hereby incorporated by reference herein) describes use of ribozymes as therapeutic agents for leukemias, such as chronic myelogenous leukemia (CML) by targeting the specific junction region of *bcr-abl* fusion transcripts. It indicates causing cleavage by a ribozyme at or near the breakpoint of such a hybrid chromosome, 20 specifically it includes cleavage at the sequence GUX, where X is A, U or G. The one example presented is to cleave the sequence 5' AGC AG AGUU (cleavage site) CAA AAGCCCU-3'.

Scanlon WO 91/18625, WO 91/18624, and WO 91/18913 and Snyder et al., WO93/03141 and WO94/13793 describe a ribozyme effective 25 to cleave oncogenic variants of H-ras RNA. This ribozyme is said to inhibit H-ras expression in response to external stimuli.

The invention features use of ribozymes to inhibit the development or expression of a transformed phenotype in man and other animals by modulating expression of a gene that contributes to the expression of CML. 30 Cleavage of targeted mRNAs expressed in pre-neoplastic and transformed cells elicits inhibition of the transformed state.

The invention can be used to treat cancer or pre-neoplastic conditions. Two preferred administration protocols can be used, either in vivo administration to reduce the tumor burden, or ex vivo treatment to

eradicate transformed cells from tissues such as bone marrow prior to reimplantation.

This invention features an enzymatic RNA molecule (or ribozyme) which cleaves mRNA associated with development or maintenance of CML. The mRNA targets are present in the 425 nucleotides surrounding the fusion sites of the *bcr* and *abl* sequences in the b2-a2 and b3-a2 recombinant mRNAs. Other sequences in the 5' portion of the *bcr* mRNA or the 3' portion of the *abl* mRNA may also be targeted for ribozyme cleavage. Cleavage at any of these sites in the fusion mRNA molecules will result in inhibition of translation of the fusion protein in treated cells.

The invention provides a class of chemical cleaving agents which exhibit a high degree of specificity for the mRNA causative of CML. Such enzymatic RNA molecules can be delivered exogenously or endogenously to afflicted cells. In the preferred hammerhead motif the small size (less than 40 nucleotides, preferably between 32 and 36 nucleotides in length) of the molecule allows the cost of treatment to be reduced.

The smallest ribozyme delivered for any type of treatment reported to date (by Rossi et al., 1992 *supra*) is an *in vitro* transcript having a length of 142 nucleotides. Synthesis of ribozymes greater than 100 nucleotides in length is very difficult using automated methods, and the therapeutic cost of such molecules is prohibitive. Delivery of ribozymes by expression vectors is primarily feasible using only *ex vivo* treatments. This limits the utility of this approach. In this invention, an alternative approach uses smaller ribozyme motifs and exogenous delivery. The simple structure of these molecules also increases the ability of the ribozyme to invade targeted regions of the mRNA structure. Thus, unlike the situation when the hammerhead structure is included within longer transcripts, there are no non-ribozyme flanking sequences to interfere with correct folding of the ribozyme structure, as well as complementary binding of the ribozyme to the mRNA target.

The enzymatic RNA molecules of this invention can be used to treat human CML or precancerous conditions. Affected animals can be treated at the time of cancer detection or in a prophylactic manner. This timing of treatment will reduce the number of affected cells and disable cellular

replication. This is possible because the ribozymes are designed to disable those structures required for successful cellular proliferation.

Ribozymes of this invention block to some extent p210<sup>bcr-abl</sup> expression and can be used to treat disease or diagnose such disease.

- 5 Ribozymes will be delivered to cells in culture and to tissues in animal models of CML. Ribozyme cleavage of *bcr/abl* mRNA in these systems may prevent or alleviate disease symptoms or conditions.

- 10 The sequence of human *bcr/abl* mRNA can be screened for accessible sites using a computer folding algorithm. Regions of the mRNA that did not form secondary folding structures and that contain potential hammerhead or hairpin ribozyme cleavage sites can be identified. These sites are shown in Table 29 (All sequences are 5' to 3' in the tables). The nucleotide base position is noted in the Tables as that site to be cleaved by the designated type of ribozyme.

- 15 The sequences of the chemically synthesized ribozymes most useful in this study are shown in Table 30. Those in the art will recognize that these sequences are representative only of many more such sequences where the enzymatic portion of the ribozyme (all but the binding arms) is altered to affect activity. For example, stem-loop II sequence of  
20 hammerhead ribozymes listed in Table 30 (5'-GGCCGAAAGGCC-3') can be altered (substitution, deletion, and/or insertion) to contain any sequence provided, a minimum of two base-paired stem structure can form. The sequences listed in Tables 30 may be formed of ribonucleotides or other nucleotides or non-nucleotides. Such ribozymes are equivalent to the  
25 ribozymes described specifically in the Tables.

By engineering ribozyme motifs we have designed several ribozymes directed against *bcr-abl* mRNA sequences. These have been synthesized with modifications that improve their nuclease resistance as described above. These ribozymes cleave *bcr-abl* target sequences *in vitro*.

- 30 The ribozymes are tested for function *in vivo* by exogenous delivery to cells expressing *bcr-abl*. Ribozymes are delivered by incorporation into liposomes, by complexing with cationic lipids, by microinjection, or by expression from DNA vectors. Expression of *bcr-abl* is monitored by ELISA, by indirect immunofluoresence, and/or by FACS analysis. Levels of

*bcr-abl* mRNA are assessed by Northern analysis, RNase protection, by primer extension analysis or by quantitative RT-PCR techniques. Ribozymes that block the induction of p210<sup>*bcr-abl*</sup> protein and mRNA by more than 20% are identified.

5 Example 6: RSV

This invention relates to the use of ribozymes as inhibitors of respiratory syncytial virus (RSV) production, and in particular, the inhibition of RSV replication.

RSV is a member of the virus family paramyxoviridae and is classified  
10 under the genus *Pneumovirus* (for a review see McIntosh and Chanock, 1990 in *Virology* ed. B.N. Fields, pp. 1045, Raven Press Ltd. NY). The infectious virus particle is composed of a nucleocapsid enclosed within an envelope. The nucleocapsid is composed of a linear negative single-stranded non-segmented RNA associated with repeating subunits of  
15 capsid proteins to form a compact structure and thereby protect the RNA from nuclease degradation. The entire nucleocapsid is enclosed by the envelope. The size of the virus particle ranges from 150 - 300 nm in diameter. The complete life cycle of RSV takes place in the cytoplasm of infected cells and the nucleocapsid never reaches the nuclear  
20 compartment (Hall, 1990 in *Principles and Practice of Infectious Diseases* ed. Mandell et al., Churchill Livingstone, NY).

The RSV genome encodes ten viral proteins essential for viral production. RSV protein products include two structural glycoproteins (G and F) found in the envelope spikes, two matrix proteins [M and M2 (22K)]  
25 found in the inner membrane, three proteins localized in the nucleocapsid (N, P and L), one protein that is present on the surface of the infected cell (SH), and two nonstructural proteins [NS1 (1C) and NS2 (1B)] found only in the infected cell. The mRNAs for the 10 RSV proteins have similar 5' and 3' ends. UV-inactivation studies suggest that a single promoter is used  
30 with multiple transcription initiation sites (Barik *et al.*, 1992 *J. Virol.* 66, 6813). The order of transcription corresponding to the protein assignment on the genomic RNA is 1C, 1B, N, P, M, SH, G, F, 22K and L genes (Huang *et al.*, 1985 *Virus Res.* 2, 157) and transcript abundance corresponds to the order of gene assignment (for example the 1C and 1B mRNAs are  
35 much more abundant than the L mRNA. Synthesis of viral message begins

immediately after RSV infection of cells and reaches a maximum at 14 hours post-infection (McIntosh and Chanock, *supra*).

There are two antigenic subgroups of RSV, A and B, which can circulate simultaneously in the community in varying proportions in different years (McIntosh and Chanock, *supra*). Subgroup A usually predominates. Within the two subgroups there are numerous strains. By the limited sequence analysis available it seems that homology at the nucleotide level is more complete within than between subgroups, although sequence divergence has been noted within subgroups as well. Antigenic determinates result primarily from both surface glycoproteins, F and G. For F, at least half of the neutralization epitopes have been stably maintained over a period of 30 years. For G however, A and B subgroups may be related antigenically by as little as a few percent. On the nucleotide level, however, the majority of the divergence in the coding region of G is found in the sequence for the extracellular domain (Johnson et al., 1987, *Proc. Natl. Acad. Sci. USA* 84, 5625).

Respiratory Syncytial Virus (RSV) is the major cause of lower respiratory tract illness during infancy and childhood (Hall, *supra*) and as such is associated with an estimated 90,000 hospitalizations and 4500 deaths in the United States alone (Update: respiratory syncytial virus activity - United States, 1993, *Mmwr Morb Mortal Wkly Rep*, 42, 971). Infection with RSV generally outranks all other microbial agents leading to both pneumonia and bronchitis. While primarily affecting children under two years of age, immunity is not complete and reinfection of older children and adults, especially hospital care givers (McIntosh and Chanock, *supra*), is not uncommon. Immunocompromised patients are severely affected and RSV infection is a major complication for patients undergoing bone marrow transplantation.

Uneventful RSV respiratory disease resembles a common cold and recovery is in 7 to 12 days. Initial symptoms (rhinorrhea, nasal congestion, slight fever, etc.) are followed in 1 to 3 days by lower respiratory tract signs of infection that include a cough and wheezing. In severe cases, these mild symptoms quickly progress to tachypnea, cyanosis, and listlessness and hospitalization is required. In infants with underlying cardiac or respiratory disease, the progression of symptoms is especially rapid and can lead to respiratory failure by the second or third day of illness. With



modern intensive care however, overall mortality is usually less than 5% of hospitalized patients (McIntosh and Chanock, *supra*).

At present, neither an efficient vaccine nor a specific antiviral agent is available. An immune response to the viral surface glycoproteins can provide resistance to RSV in a number of experimental animals, and a subunit vaccine has been shown to be effective for up to 6 months in children previously hospitalized with an RSV infection (Tristram *et al.*, 1993, J. Infect. Dis. 167, 191). An attenuated bovine RSV vaccine has also been shown to be effective in calves for a similar length of time (Kubota *et al.*, 1992 J. Vet. Med. Sci. 54, 957). Previously however, a formalin-inactivated RSV vaccine was implicated in greater frequency of severe disease in subsequent natural infections with RSV (Connors *et al.*, 1992 J. Virol. 66, 7444).

The current treatment for RSV infection requiring hospitalization is the use of aerosolized ribavirin, a guanosine analog [Antiviral Agents and Viral Diseases of Man, 3rd edition. 1990. (eds. G.J. Galasso, R.J. Whitley, and T.C. Merigan) Raven Press Ltd., NY.]. Ribavirin therapy is associated with a decrease in the severity of the symptoms, improved arterial oxygen and a decrease in the amount of viral shedding at the end of the treatment period. It is not certain, however, whether ribavirin therapy actually shortens the patients' hospital stay or diminishes the need for supportive therapies (McIntosh and Chanock, *supra*). The benefits of ribavirin therapy are especially clear for high risk infants, those with the most serious symptoms or for patients with underlying bronchopulmonary or cardiac disease. Inhibition of the viral polymerase complex is supported as the main mechanism for inhibition of RSV by ribavirin, since viral but not cellular polypeptide synthesis is inhibited by ribavirin in RSV-infected cells (Antiviral Agents and Viral Diseases of Man, 3rd edition. 1990. (eds. G.J. Galasso, R.J. Whitley, and T.C. Merigan) Raven Press Ltd., NY). Since ribavirin is at least partially effective against RSV infection when delivered by aerosolization, it can be assumed that the target cells are at or near the epithelial surface. In this regard, RSV antigen had not spread any deeper than the superficial layers of the respiratory epithelium in autopsy studies of fatal pneumonia (McIntosh and Chanock, *supra*).

Jennings *et al.*, WO 94/13688 indicates that targets for specific types of ribozymes include respiratory syncytical virus.

The invention features novel enzymatic RNA molecules, or ribozymes, and methods for their use for inhibiting production of respiratory syncytial virus (RSV). Such ribozymes can be used in a method for treatment of diseases caused by these related viruses in man and other animals. The invention also features cleavage of the genomic RNA and mRNA of these viruses by use of ribozymes. In particular, the ribozyme molecules described are targeted to the *NS1 (1C)*, *NS2 (1B)* and *N* viral genes. These genes are known in the art (for a review see McIntosh and Chanock, 1990 *supra*).

Ribozymes that cleave the specified sites in RSV mRNAs represent a novel therapeutic approach to respiratory disorders. Applicant indicates that ribozymes are able to inhibit the activity of RSV and that the catalytic activity of the ribozymes is required for their inhibitory effect. Those of ordinary skill in the art, will find that it is clear from the examples described that other ribozymes that cleave these sites in RSV mRNAs encoding 1C, 1B and N proteins may be readily designed and are within the invention. Also, those of ordinary skill in the art, will find that it is clear from the examples described that ribozymes cleaving other mRNAs encoded by RSV (*P*, *M*, *SH*, *G*, *F*, *22K* and *L*) and the genomic RNA may be readily designed and are within the invention.

In preferred embodiments, the ribozymes have binding arms which are complementary to the sequences in Tables 31, 33, 35, 37 and 38. Examples of such ribozymes are shown in Tables 32, 34, 36-38. Examples of such ribozymes consist essentially of sequences defined in these Tables. By "consists essentially of" is meant that the active ribozyme contains an enzymatic center equivalent to those in the examples, and binding arms able to bind mRNA such that cleavage at the target site occurs. Other sequences may be present which do not interfere with such cleavage.

Ribozymes of this invention block to some extent RSV production and can be used to treat disease or diagnose such disease. Ribozymes will be delivered to cells in culture and to cells or tissues in animal models of respiratory disorders. Ribozyme cleavage of RSV encoded mRNAs or the genomic RNA in these systems may alleviate disease symptoms.

While all ten RSV encoded proteins (1C, 1B, N, P, M, SH, 22K, F, G, and L) are essential for viral life cycle and are all potential targets for ribozyme cleavage, certain proteins (mRNAs) are more favorable for ribozyme targeting than the others. For example RSV encoded proteins 1C, 1B, SH and 22K are not found in other members of the family paramyxoviridae and appear to be unique to RSV. In contrast the ectodomain of the G protein and the signal sequence of the F protein show significant sequence divergence at the nucleotide level among various RSV sub-groups (Johnson *et al.*, 1987 *supra*). RSV proteins 1C, 1B and N are highly conserved among various subtypes at both the nucleotide and amino acid levels. Also, 1C, 1B and N are the most abundant of all RSV proteins.

The sequence of human RSV mRNAs encoding 1C, 1B and N proteins are screened for accessible sites using a computer folding algorithm. Hammerhead or hairpin ribozyme cleavage sites were identified. These sites are shown in Tables 31, 33, 34, 37 and 38 (All sequences are 5' to 3' in the tables.) The nucleotide base position is noted in the Tables as that site to be cleaved by the designated type of ribozyme.

Ribozymes of the hammerhead or hairpin motif are designed to anneal to various sites in the mRNA message. The binding arms are complementary to the target site sequences described above. The ribozymes are chemically synthesized. The method of synthesis used follows the procedure for normal RNA synthesis as described in Usman *et al.*, 1987 J. Am. Chem. Soc., 109, 7845-7854 and in Scaringe *et al.*, 1990 Nucleic Acids Res., 18, 5433-5441 and makes use of common nucleic acid protecting and coupling groups, such as dimethoxytrityl at the 5'-end, and phosphoramidites at the 3'-end. The average stepwise coupling yields were >98%. Inactive ribozymes were synthesized by substituting a U for G5 and a U for A14 (numbering from Hertel *et al.*, 1992 Nucleic Acids Res., 20, 3252). Hairpin ribozymes are synthesized in two parts and annealed to reconstruct the active ribozyme (Chowrira and Burke, 1992 Nucleic Acids Res., 20, 2835-2840). Hairpin ribozymes are also synthesized from DNA templates using bacteriophage T7 RNA polymerase (Milligan and Uhlenbeck, 1989, *Methods Enzymol.* 180, 51). All ribozymes are modified extensively to enhance stability by modification with nuclease resistant

groups, for example, 2'-amino, 2'-C-allyl, 2'-fluoro, 2'-O-methyl, 2'-H (for a review see Usman and Cedergren, 1992 *TIBS* 17, 34). Ribozymes are purified by gel electrophoresis using general methods or are purified by high pressure liquid chromatography and are resuspended in water.

5       The sequences of the chemically synthesized ribozymes useful in this study are shown in Tables 32, 34, 36, 37 and 38. Those in the art will recognize that these sequences are representative only of many more such sequences where the enzymatic portion of the ribozyme (all but the binding arms) is altered to affect activity. For example, stem-loop II sequence of  
10 hammerhead ribozymes listed in Tables 32 and 34 (5'-GGCCGAAAGGCC-3') can be altered (substitution, deletion, and/or insertion) to contain any sequences provided a minimum of two base-paired stem structure can form. Similarly, stem-loop IV sequence of hairpin ribozymes listed in  
15 Tables 37 and 38 (5'-CACGUUGUG-3') can be altered (substitution, deletion, and/or insertion) to contain any sequence, provided a minimum of two base-paired stem structure can form. The sequences listed in Tables 32, 34, 36, 37 and 38 may be formed of ribonucleotides or other nucleotides or non-nucleotides. Such ribozymes are equivalent to the ribozymes described specifically in the Tables.

20       By engineering ribozyme motifs we have designed several ribozymes directed against RSV encoded mRNA sequences. These ribozymes are synthesized with modifications that improve their nuclease resistance. The ability of ribozymes to cleave target sequences *in vitro* is evaluated.

25       Numerous common cell lines can be infected with RSV for experimental purposes. These include *HeLa*, *Vero* and several primary epithelial cell lines. A cotton rat animal model of experimental human RSV infection is also available, and the bovine RSV is quite homologous to the human viruses. Rapid clinical diagnosis is through the use of kits designed for the immunofluorescence staining of RSV-infected cells or an ELISA  
30 assay, both of which are adaptable for experimental study. RSV encoded mRNA levels will be assessed by Northern analysis, RNase protection, primer extension analysis or quantitative RT-PCR. Ribozymes that block the induction of RSV activity and/or 1C, 1B and N protein encoding mRNAs by more than 90% will be identified.

Optimizing Ribozyme Activity

Ribozyme activity can be optimized as described by Draper et al., PCT WO93/23569. The details will not be repeated here, but include altering the length of the ribozyme binding arms or chemically synthesizing ribozymes with modifications that prevent their degradation by serum ribonucleases (see e.g., Eckstein et al., International Publication No. WO 92/07065; Perrault et al., 1990 Nature 344, 565; Pieken et al., 1991 Science 253, 314; Usman and Cedergren, 1992 Trends in Biochem. Sci. 17, 334; Usman et al., International Publication No. WO 93/15187; and Rossi et al., International Publication No. WO 91/03162, as well as Jennings et al., WO 94/13688, which describe various chemical modifications that can be made to the sugar moieties of enzymatic RNA molecules. All these publications are hereby incorporated by reference herein.), modifications which enhance their efficacy in cells, and removal of stem II bases to shorten RNA synthesis times and reduce chemical requirements.

Sullivan, et al., PCT WO94/02595, incorporated by reference herein, describes the general methods for delivery of enzymatic RNA molecules. Ribozymes may be administered to cells by a variety of methods known to those familiar to the art, including, but not restricted to, encapsulation in liposomes, by iontophoresis, or by incorporation into other vehicles, such as hydrogels, cyclodextrins, biodegradable nanocapsules, and bioadhesive microspheres. The RNA/vehicle combination is locally delivered by direct injection or by use of a catheter, infusion pump or stent. Alternative routes of delivery include, but are not limited to, intravenous injection, intramuscular injection, subcutaneous injection, aerosol inhalation, oral (tablet or pill form), topical, systemic, ocular, intraperitoneal and/or intrathecal delivery. More detailed descriptions of ribozyme delivery and administration are provided in Sullivan, et al., supra and Draper, et al., supra which have been incorporated by reference herein.

Another means of accumulating high concentrations of a ribozyme(s) within cells is to incorporate the ribozyme-encoding sequences into a DNA expression vector. Transcription of the ribozyme sequences are driven from a promoter for eukaryotic RNA polymerase I (pol I), RNA polymerase II (pol II), or RNA polymerase III (pol III). Transcripts from pol II or pol III promoters will be expressed at high levels in all cells; the levels of a given

pol II promoter in a given cell type will depend on the nature of the gene regulatory sequences (enhancers, silencers, etc.) present nearby. Prokaryotic RNA polymerase promoters are also used, providing that the prokaryotic RNA polymerase enzyme is expressed in the appropriate cells

5 (Elroy-Stein and Moss, 1990 Proc. Natl. Acad. Sci. U S A, 87, 6743-7; Gao and Huang 1993 Nucleic Acids Res., 21, 2867-72; Lieber et al., 1993 Methods Enzymol., 217, 47-66; Zhou et al., 1990 Mol. Cell. Biol., 10, 4529-37). Several investigators have demonstrated that ribozymes expressed from such promoters can function in mammalian cells (e.g. Kashani-Sabet

10 et al., 1992 Antisense Res. Dev., 2, 3-15; Ojwang et al., 1992 Proc. Natl. Acad. Sci. U S A, 89, 10802-6; Chen et al., 1992 Nucleic Acids Res., 20, 4581-9; Yu et al., 1993 Proc. Natl. Acad. Sci. U S A, 90, 6340-4; L'Huillier et al., 1992 EMBO J., 11, 4411-8; Lisiewicz et al., 1993 Proc. Natl. Acad. Sci. U. S. A., 90, 8000-4). The above ribozyme transcription units can be

15 incorporated into a variety of vectors for introduction into mammalian cells, including but not restricted to, plasmid DNA vectors, viral DNA vectors (such as adenovirus or adeno-associated virus vectors), or viral RNA vectors (such as retroviral, or alpha virus vectors).

In a preferred embodiment of the invention, a transcription unit

20 expressing a ribozyme that cleaves target RNA is inserted into a plasmid DNA vector, a retrovirus DNA viral vector, an adenovirus DNA viral vector or an adeno-associated virus vector or alpha virus vector. These and other vectors have been used to transfer genes to live animals (for a review see Friedman, 1989 Science 244, 1275-1281; Roemer and Friedman, 1992

25 Eur. J. Biochem. 208, 211-225) and leads to transient or stable gene expression. The vectors are delivered as recombinant viral particles. DNA may be delivered alone or complexed with vehicles (as described for RNA above). The DNA, DNA/vehicle complexes, or the recombinant virus particles are locally administered to the site of treatment, e.g., through the

30 use of a catheter, stent or infusion pump.

#### Diagnostic uses

Ribozymes of this invention may be used as diagnostic tools to examine genetic drift and mutations within diseased cells. The close relationship between ribozyme activity and the structure of the target RNA

35 allows the detection of mutations in any region of the molecule which alters the base-pairing and three-dimensional structure of the target RNA. By

using multiple ribozymes described in this invention, one may map nucleotide changes which are important to RNA structure and function *in vitro*, as well as in cells and tissues. Cleavage of target RNAs with ribozymes may be used to inhibit gene expression and define the role  
5 (essentially) of specified gene products in the progression of disease. In this manner, other genetic targets may be defined as important mediators of the disease. These experiments will lead to better treatment of the disease progression by affording the possibility of combinational therapies (e.g., multiple ribozymes targeted to different genes, ribozymes coupled  
10 with known small molecule inhibitors, or intermittent treatment with combinations of ribozymes and/or other chemical or biological molecules). Other *in vitro* uses of ribozymes of this invention are well known in the art, and include detection of the presence of mRNA associated with ICAM-1, relA, TNF- $\alpha$ , p210, bcr-abl or RSV related condition. Such RNA is detected  
15 by determining the presence of a cleavage product after treatment with a ribozyme using standard methodology.

In a specific example, ribozymes which can cleave only wild-type or mutant forms of the target RNA are used for the assay. The first ribozyme is used to identify wild-type RNA present in the sample and the second  
20 ribozyme will be used to identify mutant RNA in the sample. As reaction controls, synthetic substrates of both wild-type and mutant RNA will be cleaved by both ribozymes to demonstrate the relative ribozyme efficiencies in the reactions and the absence of cleavage of the "non-targeted" RNA species. The cleavage products from the synthetic  
25 substrates will also serve to generate size markers for the analysis of wild-type and mutant RNAs in the sample population. Thus each analysis will require two ribozymes, two substrates and one unknown sample which will be combined into six reactions. The presence of cleavage products will be determined using an RNase protection assay so that full-length and  
30 cleavage fragments of each RNA can be analyzed in one lane of a polyacrylamide gel. It is not absolutely required to quantify the results to gain insight into the expression of mutant RNAs and putative risk of the desired phenotypic changes in target cells. The expression of mRNA whose protein product is implicated in the development of the phenotype  
35 (i.e., ICAM-1, rel A, TNF $\alpha$ , p210bcr-abl or RSV) is adequate to establish risk. If probes of comparable specific activity are used for both transcripts, then a qualitative comparison of RNA levels will be adequate and will

decrease the cost of the initial diagnosis. Higher mutant form to wild-type ratios will be correlated with higher risk whether RNA levels are compared qualitatively or quantitatively.

## II. Chemical Synthesis Of Ribozymes

- 5        There follows the chemical synthesis, deprotection, and purification of RNA, enzymatic RNA or modified RNA molecules in greater than milligram quantities with high biological activity. Applicant has determined that the synthesis of enzymatically active RNA in high yield and quantity is dependent upon certain critical steps used during its preparation.
- 10       Specifically, it is important that the RNA phosphoramidites are coupled efficiently in terms of both yield and time, that correct exocyclic amino protecting groups be used, that the appropriate conditions for the removal of the exocyclic amino protecting groups and the alkylsilyl protecting groups on the 2'-hydroxyl are used, and that the correct work-up and
- 15       purification procedure of the resulting ribozyme be used.

- To obtain a correct synthesis in terms of yield and biological activity of a large RNA molecule (*i.e.*, about 30 to 40 nucleotide bases), the protection of the amino functions of the bases requires either amide or substituted amide protecting groups, which must be, on the one hand, stable enough
- 20       to survive the conditions of synthesis, and on the other hand, removable at the end of the synthesis. These requirements are met by the amide protecting groups shown in Figure 8, in particular, benzoyl for adenosine, isobutyryl or benzoyl for cytidine, and isobutyryl for guanosine, which may be removed at the end of the synthesis by incubating the RNA in  $\text{NH}_3/\text{EtOH}$
- 25       (ethanolic ammonia) for 20 h at 65 °C. In the case of the phenoxyacetyl type protecting groups shown in Figure 8 on guanosine and adenosine and acetyl protecting groups on cytidine, an incubation in ethanolic ammonia for 4 h at 65 °C is used to obtain complete removal of these protecting groups. Removal of the alkylsilyl 2'-hydroxyl protecting groups
- 30       can be accomplished using a tetrahydrofuran solution of TBAF at room temperature for 8-24 h.

- The most quantitative procedure for recovering the fully deprotected RNA molecule is by either ethanol precipitation, or an anion exchange cartridge desalting, as described in Scaringe *et al. Nucleic Acids Res.*
- 35       1990, 18, 5433-5341. The purification of the long RNA sequences may be



accomplished by a two-step chromatographic procedure in which the molecule is first purified on a reverse phase column with either the trityl group at the 5' position on or off. This purification is accomplished using an acetonitrile gradient with triethylammonium or bicarbonate salts as the aqueous phase. In the case of the trityl on purification, the trityl group may be removed by the addition of an acid and drying of the partially purified RNA molecule. The final purification is carried out on an anion exchange column, using alkali metal perchlorate salt gradients to elute the fully purified RNA molecule as the appropriate metal salts, e.g. Na<sup>+</sup>, Li<sup>+</sup> etc. A final de-salting step on a small reverse-phase cartridge completes the purification procedure. Applicant has found that such a procedure not only fails to adversely affect activity of a ribozyme, but may improve its activity to cleave target RNA molecules.

Applicant has also determined that significant (see Tables 39-41) improvements in the yield of desired full length product (FLP) can be obtained by:

1. Using 5-S-alkyltetrazole at a delivered or effective concentration of 0.25-0.5 M or 0.15-0.35 M for the activation of the RNA (or analogue) amidite during the coupling step. (By delivered is meant that the actual amount of chemical in the reaction mix is known. This is possible for large scale synthesis since the reaction vessel is of size sufficient to allow such manipulations. The term effective means that available amount of chemical actually provided to the reaction mixture that is able to react with the other reagents present in the mixture. Those skilled in the art will recognize the meaning of these terms from the examples provided herein.) The time for this step is shortened from 10-15 m, *vide supra*, to 5-10 m. Alkyl, as used herein, refers to a saturated aliphatic hydrocarbon, including straight-chain, branched-chain, and cyclic alkyl groups. Preferably, the alkyl group has 1 to 12 carbons. More preferably it is a lower alkyl of from 1 to 7 carbons, more preferably 1 to 4 carbons. The alkyl group may be substituted or unsubstituted. When substituted the substituted group(s) is preferably, hydroxyl, cyano, alkoxy, =O, =S, NO<sub>2</sub> or N(CH<sub>3</sub>)<sub>2</sub>, amino, or SH. The term also includes alkenyl groups which are unsaturated hydrocarbon groups containing at least one carbon-carbon double bond, including straight-chain, branched-chain, and cyclic groups. Preferably, the alkenyl group has 1 to 12 carbons. More preferably it is a lower alkenyl of from 1 to

7 carbons, more preferably 1 to 4 carbons. The alkenyl group may be substituted or unsubstituted. When substituted the substituted group(s) is preferably, hydroxyl, cyano, alkoxy, =O, =S, NO<sub>2</sub>, halogen, N(CH<sub>3</sub>)<sub>2</sub>, amino, or SH. The term "alkyl" also includes alkynyl groups which have an

5 unsaturated hydrocarbon group containing at least one carbon-carbon triple bond, including straight-chain, branched-chain, and cyclic groups. Preferably, the alkynyl group has 1 to 12 carbons. More preferably it is a lower alkynyl of from 1 to 7 carbons, more preferably 1 to 4 carbons. The alkynyl group may be substituted or unsubstituted. When substituted the

10 substituted group(s) is preferably, hydroxyl, cyano, alkoxy, =O, =S, NO<sub>2</sub> or N(CH<sub>3</sub>)<sub>2</sub>, amino or SH.

Such alkyl groups may also include aryl, alkylaryl, carbocyclic aryl, heterocyclic aryl, amide and ester groups. An "aryl" group refers to an aromatic group which has at least one ring having a conjugated  $\pi$  electron

15 system and includes carbocyclic aryl, heterocyclic aryl and biaryl groups, all of which may be optionally substituted. The preferred substituent(s) of aryl groups are halogen, trihalomethyl, hydroxyl, SH, OH, cyano, alkoxy, alkyl, alkenyl, alkynyl, and amino groups. An "alkylaryl" group refers to an alkyl group (as described above) covalently joined to an aryl group (as

20 described above). Carbocyclic aryl groups are groups wherein the ring atoms on the aromatic ring are all carbon atoms. The carbon atoms are optionally substituted. Heterocyclic aryl groups are groups having from 1 to 3 heteroatoms as ring atoms in the aromatic ring and the remainder of the ring atoms are carbon atoms. Suitable heteroatoms include oxygen, sulfur,

25 and nitrogen, and include furanyl, thienyl, pyridyl, pyrrolyl, N-lower alkyl pyrrolo, pyrimidyl, pyrazinyl, imidazolyl and the like, all optionally substituted. An "amide" refers to an -C(O)-NH-R, where R is either alkyl, aryl, alkylaryl or hydrogen. An "ester" refers to an -C(O)-OR', where R is either alkyl, aryl, alkylaryl or hydrogen.

30 2. Using 5-S-alkyltetrazole at an effective, or final, concentration of 0.1-0.35 M for the activation of the RNA (or analogue) amidite during the coupling step. The time for this step is shortened from 10-15 m, *vide supra*, to 5-10 m.

35 3. Using alkylamine (MA, where alkyl is preferably methyl, ethyl, propyl or butyl) or NH<sub>4</sub>OH/alkylamine (AMA, with the same preferred alkyl groups as noted for MA) @ 65 °C for 10-15 m to remove the exocyclic

amino protecting groups (vs 4-20 h @ 55-65 °C using NH<sub>4</sub>OH/EtOH or NH<sub>3</sub>/EtOH, *vide supra*). Other alkylamines, e.g. ethylamine, propylamine, butylamine *etc.* may also be used.

4. Using anhydrous triethylamine•hydrogen fluoride (aHF•TEA)  
5 @ 65 °C for 0.5-1.5 h to remove the 2'-hydroxyl alkylsilyl protecting group (vs 8 - 24 h using TBAF, *vide supra* or TEA•3HF for 24 h (Gasparutto *et al. Nucleic Acids Res.* 1992, 20, 5159-5166). Other alkylamine•HF complexes may also be used, e.g. trimethylamine or diisopropylethylamine.

5. The use of anion-exchange resins to purify and/or analyze the  
10 fully deprotected RNA. These resins include, but are not limited to, quaternary or tertiary amino derivatized stationary phases such as silica or polystyrene. Specific examples include Dionex-NA100®, Mono-Q®, Poros-Q®.

- Thus, the invention features an improved method for the coupling of  
15 RNA phosphoramidites; for the removal of amide or substituted amide protecting groups; and for the removal of 2'-hydroxyl alkylsilyl protecting groups. Such methods enhance the production of RNA or analogs of the type described above (e.g., with substituted 2'-groups), and allow efficient synthesis of large amounts of such RNA. Such RNA may also have  
20 enzymatic activity and be purified without loss of that activity. While specific examples are given herein, those in the art will recognize that equivalent chemical reactions can be performed with the alternative chemicals noted above, which can be optimized and selected by routine experimentation.

- In another aspect, the invention features an improved method for the  
25 purification or analysis of RNA or enzymatic RNA molecules (e.g. 28-70 nucleotides in length) by passing said RNA or enzymatic RNA molecule over an HPLC, e.g., reverse phase and/or an anion exchange chromatography column. The method of purification improves the catalytic activity of enzymatic RNAs over the gel purification method (see Figure 10).

- 30 Draper *et al.*, PCT WO93/23569, incorporated by reference herein, disclosed reverse phase HPLC purification. The purification of long RNA molecules may be accomplished using anion exchange chromatography, particularly in conjunction with alkali perchlorate salts. This system may be used to purify very long RNA molecules. In particular, it is advantageous to

use a Dionex NucleoPak 100<sup>®</sup> or a Pharmacia Mono Q<sup>®</sup> anion exchange column for the purification of RNA by the anion exchange method. This anion exchange purification may be used following a reverse-phase purification or prior to reverse phase purification. This method results in the formation of a sodium salt of the ribozyme during the chromatography. Replacement of the sodium alkali earth salt by other metal salts, *e.g.*, lithium, magnesium or calcium perchlorate, yields the corresponding salt of the RNA molecule during the purification.

In the case of the 2-step purification procedure, in which the first step is a reverse phase purification followed by an anion exchange step, the reverse phase purification is best accomplished using polymeric, *e.g.* polystyrene based, reverse-phase media, using either a 5'-trityl-on or 5'-trityl-off method. Either molecule may be recovered using this reverse-phase method, and then, once detritylated, the two fractions may be pooled and then submitted to an anion exchange purification step as described above.

The method includes passing the enzymatically active RNA molecule over a reverse phase HPLC column; the enzymatically active RNA molecule is produced in a synthetic chemical method and not by an enzymatic process; and the enzymatic RNA molecule is partially blocked, and the partially blocked enzymatically active RNA molecule is passed over a reverse phase HPLC column to separate it from other RNA molecules.

In more preferred embodiments, the enzymatically active RNA molecule, after passage over the reverse phase HPLC column, is deprotected and passed over a second reverse phase HPLC column (which may be the same as the reverse phase HPLC column), to remove the enzymatic RNA molecule from other components. In addition, the column is a silica or organic polymer-based C4, C8 or C18 column having a porosity of at least 125 Å, preferably 300 Å, and a particle size of at least 2 µm, preferably 5 µm.

#### Activation

The synthesis of RNA molecules may be accomplished chemically or enzymatically. In the case of chemical synthesis the use of tetrazole as an activator of RNA phosphoramidites is known (Usman *et al.* *J. Am. Chem.*

Soc. 1987, 109, 7845-7854). In this, and subsequent reports, a 0.5 M solution of tetrazole is allowed to react with the RNA phosphoramidite and couple with the polymer bound 5'-hydroxyl group for 10 m. Applicant has determined that using 0.25-0.5 M solutions of 5-S-alkyltetrazoles for only 5 min gives equivalent or better results. The following exemplifies the procedure.

Example 7: Synthesis of RNA and Ribozymes Using 5-S-Alkyltetrazoles as Activating Agent

The method of synthesis used follows the general procedure for RNA synthesis as described in Usman et al., 1987 *supra* and in Scaringe et al., *Nucleic Acids Res.* 1990, 18, 5433-5441 and makes use of common nucleic acid protecting and coupling groups, such as dimethoxytrityl at the 5'-end, and phosphoramidites at the 3'-end. The major difference used was the activating agent, 5-S-ethyl or -methyltetrazole @ 0.25 M concentration for 5 min.

All small scale syntheses were conducted on a 394 (ABI) synthesizer using a modified 2.5  $\mu$ mol scale protocol with a reduced 5 min coupling step for alkylsilyl protected RNA and 2.5 m coupling step for 2'-O-methylated RNA. A 6.5-fold excess (162.5  $\mu$ L of 0.1 M = 32.5  $\mu$ mol) of phosphoramidite and a 40-fold excess of S-ethyl tetrazole (400  $\mu$ L of 0.25 M = 100  $\mu$ mol) relative to polymer-bound 5'-hydroxyl was used in each coupling cycle. Average coupling yields on the 394, determined by colorimetric quantitation of the trityl fractions, was 97.5-99%. Other oligonucleotide synthesis reagents for the 394: Detritylation solution was 2% TCA in methylene chloride; capping was performed with 16% N-Methyl imidazole in THF and 10% acetic anhydride/10% 2,6-lutidine in THF; oxidation solution was 16.9 mM I<sub>2</sub>, 49 mM pyridine, 9% water in THF. Fisher Synthesis Grade acetonitrile was used directly from the reagent bottle. S-Ethyl tetrazole solution (0.25 M in acetonitrile) was made up from the solid obtained from Applied Biosystems.

All large scale syntheses were conducted on a modified (eight amidite port capacity) 390Z (ABI) synthesizer using a 25  $\mu$ mol scale protocol with a 5-15 min coupling step for alkylsilyl protected RNA and 7.5 m coupling step for 2'-O-methylated RNA. A six-fold excess (1.5 mL of 0.1 M = 150  $\mu$ mol) of phosphoramidite and a forty-five-fold excess of S-ethyl tetrazole (4.5 mL of

0.25 M = 1125  $\mu$ mol) relative to polymer-bound 5'-hydroxyl was used in each coupling cycle. Average coupling yields on the 390Z, determined by colorimetric quantitation of the trityl fractions, was 95.0-96.7%. Oligonucleotide synthesis reagents for the 390Z: Detritylation solution was 2% DCA in methylene chloride; capping was performed with 16% *N*-Methyl imidazole in THF and 10% acetic anhydride/10% 2,6-lutidine in THF; oxidation solution was 16.9 mM I<sub>2</sub>, 49 mM pyridine, 9% water in THF. Fisher Synthesis Grade acetonitrile was used directly from the reagent bottle. S-Ethyl tetrazole solution (0.25-0.5 M in acetonitrile) was made up from the solid obtained from Applied Biosystems.

#### Deprotection

The first step of the deprotection of RNA molecules may be accomplished by removal of the exocyclic amino protecting groups with either NH<sub>4</sub>OH/EtOH:3/1 (Usman *et al. J. Am. Chem. Soc.* 1987, 109, 7845-7854) or NH<sub>3</sub>/EtOH (Scaringe *et al. Nucleic Acids Res.* 1990, 18, 5433-5341) for ~20 h @ 55-65 °C. Applicant has determined that the use of methylamine or NH<sub>4</sub>OH/methylamine for 10-15 min @ 55-65 °C gives equivalent or better results. The following exemplifies the procedure.

#### Example 8: RNA and Ribozyme Deprotection of Exocyclic Amino Protecting Groups Using Methylamine (MA) or NH<sub>4</sub>OH/Methylamine (AMA)

The polymer-bound oligonucleotide, either trityl-on or off, was suspended in a solution of methylamine (MA) or NH<sub>4</sub>OH/methylamine (AMA) @ 55-65 °C for 5-15 min to remove the exocyclic amino protecting groups. The polymer-bound oligoribonucleotide was transferred from the synthesis column to a 4 mL glass screw top vial. NH<sub>4</sub>OH and aqueous methylamine were pre-mixed in equal volumes. 4 mL of the resulting reagent was added to the vial, equilibrated for 5 m at RT and then heated at 55 or 65 °C for 5-15 min. After cooling to -20 °C, the supernatant was removed from the polymer support. The support was washed with 1.0 mL of EtOH:MeCN:H<sub>2</sub>O/3:1:1, vortexed and the supernatant was then added to the first supernatant. The combined supernatants, containing the oligoribonucleotide, were dried to a white powder. The same procedure was followed for the aqueous methylamine reagent.

Table 40 is a summary of the results obtained using the improvements outlined in this application for base deprotection.

- The second step of the deprotection of RNA molecules may be accomplished by removal of the 2'-hydroxyl alkylsilyl protecting group using TBAF for 8-24 h (Usman *et al.* *J. Am. Chem. Soc.* 1987, 109, 7845-7854). Applicant has determined that the use of anhydrous TEA•HF in *N*-methylpyrrolidine (NMP) for 0.5-1.5 h @ 55-65 °C gives equivalent or better results. The following exemplifies this procedure.

Example 9: RNA and Ribozyme Deprotection of 2'-Hydroxyl Alkylsilyl Protecting Groups Using Anhydrous TEA•HF

- To remove the alkylsilyl protecting groups, the ammonia-deprotected oligoribonucleotide was resuspended in 250 µL of 1.4 M anhydrous HF solution (1.5 mL *N*-methylpyrrolidine, 750 µL TEA and 1.0 mL TEA•3HF) and heated to 65 °C for 1.5 h. 9 mL of 50 mM TEAB was added to quench the reaction. The resulting solution was loaded onto a Qiagen 500<sup>®</sup> anion exchange cartridge (Qiagen Inc.) prewashed with 10 mL of 50 mM TEAB. After washing the cartridge with 10 mL of 50 mM TEAB, the RNA was eluted with 10 mL of 2 M TEAB and dried down to a white powder.

Table 41 is a summary of the results obtained using the improvements outlined in this application for alkylsilyl deprotection.

Example 10: HPLC Purification, Anion Exchange column

- For a small scale synthesis, the crude material was diluted to 5 mL with diethylpyrocarbonate treated water. The sample was injected onto either a Pharmacia Mono Q<sup>®</sup> 16/10 or Dionex NucleoPac<sup>®</sup> column with 100% buffer A (10 mM NaClO<sub>4</sub>). A gradient from 180-210 mM NaClO<sub>4</sub> at a rate of 0.85 mM/void volume for a Pharmacia Mono Q<sup>®</sup> anion-exchange column or 100-150 mM NaClO<sub>4</sub> at a rate of 1.7 mM/void volume for a Dionex NucleoPac<sup>®</sup> anion-exchange column was used to elute the RNA. Fractions were analyzed by a HP-1090 HPLC with a Dionex NucleoPac<sup>®</sup> column. Fractions containing full length product at ≥80% by peak area were pooled.
- For a trityl-off large scale synthesis, the crude material was desalted by applying the solution that resulted from quenching of the desilylation reaction to a 53 mL Pharmacia HiLoad 26/10 Q-Sepharose<sup>®</sup> Fast Flow column. The column was thoroughly washed with 10 mM sodium perchlorate buffer. The oligonucleotide was eluted from the column with

300 mM sodium perchlorate. The eluent was quantitated and an analytical HPLC was run to determine the percent full length material in the synthesis. The eluent was diluted four fold in sterile H<sub>2</sub>O to lower the salt concentration and applied to a Pharmacia Mono Q<sup>®</sup> 16/10 column. A gradient from 10-185 mM sodium perchlorate was run over 4 column volumes to elute shorter sequences, the full length product was then eluted in a gradient from 185-214 mM sodium perchlorate in 30 column volumes. The fractions of interest were analyzed on a HP-1090 HPLC with a Dionex NucleoPac<sup>®</sup> column. Fractions containing over 85% full length material were pooled. The pool was applied to a Pharmacia RPC<sup>®</sup> column for desalting.

For a trityl-on large scale synthesis, the crude material was desalted by applying the solution that resulted from quenching of the desilylation reaction to a 53 mL Pharmacia HiLoad 26/10 Q-Sepharose<sup>®</sup> Fast Flow column. The column was thoroughly washed with 20 mM NH<sub>4</sub>CO<sub>3</sub>H/10% CH<sub>3</sub>CN buffer. The oligonucleotide was eluted from the column with 1.5 M NH<sub>4</sub>CO<sub>3</sub>H/10% acetonitrile. The eluent was quantitated and an analytical HPLC was run to determine the percent full length material present in the synthesis. The oligonucleotide was then applied to a Pharmacia Resource RPC column. A gradient from 20-55% B (20 mM NH<sub>4</sub>CO<sub>3</sub>H/25% CH<sub>3</sub>CN, buffer A = 20 mM NH<sub>4</sub>CO<sub>3</sub>H/10% CH<sub>3</sub>CN) was run over 35 column volumes. The fractions of interest were analyzed on a HP-1090 HPLC with a Dionex NucleoPac<sup>®</sup> column. Fractions containing over 60% full length material were pooled. The pooled fractions were then submitted to manual detritylation with 80% acetic acid, dried down immediately, resuspended in sterile H<sub>2</sub>O, dried down and resuspended in H<sub>2</sub>O again. This material was analyzed on a HP 1090-HPLC with a Dionex NucleoPac<sup>®</sup> column. The material was purified by anion exchange chromatography as in the trityl-off scheme (*vide supra*).

#### Example 11 Ribozyme Activity Assay

Purified 5'-end labeled RNA substrates (15-25-mers) and purified 5'-end labeled ribozymes (~36-mers) were both heated to 95 °C, quenched on ice and equilibrated at 37 °C, separately. Ribozyme stock solutions were 1 μM, 200 nM, 40 nM or 8 nM and the final substrate RNA concentrations were ~ 1 nM. Total reaction volumes were 50 μL. The assay buffer was 50 mM Tris-Cl, pH 7.5 and 10 mM MgCl<sub>2</sub>. Reactions were



initiated by mixing substrate and ribozyme solutions at  $t = 0$ . Aliquots of 5  $\mu\text{L}$  were removed at time points of 1, 5, 15, 30, 60 and 120 m. Each aliquot was quenched in formamide loading buffer and loaded onto a 15% denaturing polyacrylamide gel for analysis. Quantitative analyses were performed using a phosphorimager (Molecular Dynamics).

Example 12: One pot deprotection of RNA

Applicant has shown that aqueous methyl amine is an efficient reagent to deprotect bases in an RNA molecule. However, in a time consuming step (2-24 hrs), the RNA sample needs to be dried completely prior to the deprotection of the sugar 2'-hydroxyl groups. Additionally, deprotection of RNA synthesized on a large scale (e.g., 100  $\mu\text{mol}$ ) becomes challenging since the volume of solid support used is quite large. In an attempt to minimize the time required for deprotection and to simplify the process of deprotection of RNA synthesized on a large scale, applicant describes a one pot deprotection protocol (Fig. 12). According to this protocol, anhydrous methylamine is used in place of aqueous methyl amine. Base deprotection is carried out at 65 °C for 15 min and the reaction is allowed to cool for 10 min. Deprotection of 2'-hydroxyl groups is then carried out in the same container for 90 min in a TEA•3HF reagent. The reaction is quenched with 16 mM TEAB solution.

Referring to Fig. 13, hammerhead ribozyme targeted to site B is synthesized using RNA phosphoramidite chemistry and deprotected using either a two pot or a one pot protocol. Profiles of these ribozymes on an HPLC column are compared. The figure shows that RNAs deprotected by either the one pot or the two pot protocols yield similar full-length product profiles. Applicant has shown that using a one pot deprotection protocol, time required for RNA deprotection can be reduced considerably without compromising the quality or the yield of full length RNA.

Referring to Fig. 14, hammerhead ribozymes targeted to site B (from Fig. 13) are tested for their ability to cleave RNA. As shown in the figure 14, ribozymes that are deprotected using one pot protocol have catalytic activity comparable to ribozymes that are deprotected using a two pot protocol.

Example 12a: Improved protocol for the synthesis of phosphorothioate containing RNA and ribozymes using 5-S-Alkyltetrazoles as Activating Agent

5 The two sulfurizing reagents that have been used to synthesize ribophosphorothioates are tetraethylthiuram disulfide (TETD; Vu and Hirschbein, 1991 *Tetrahedron Letter* 31, 3005), and 3H-1,2-benzodithiol-3-one 1,1-dioxide (Beaucage reagent; Vu and Hirschbein, 1991 *supra*). TETD requires long sulfurization times (600 seconds for DNA and 3600 seconds for RNA). It has recently been shown that for sulfurization of DNA  
10 oligonucleotides, Beaucage reagent is more efficient than TETD (Wyrzykiewicz and Ravikumar, 1994 *Bioorganic Med. Chem.* 4, 1519). Beaucage reagent has also been used to synthesize phosphorothioate oligonucleotides containing 2'-deoxy-2'-fluoro modifications wherein the wait time is 10 min (Kawasaki et al., 1992 *J. Med. Chem.*).

15 The method of synthesis used follows the procedure for RNA synthesis as described herein and makes use of common nucleic acid protecting and coupling groups, such as dimethoxytrityl at the 5'-end, and phosphoramidites at the 3'-end. The sulfurization step for RNA described in the literature is a 8 second delivery and 10 min wait steps (Beaucage  
20 and Iyer, 1991 *Tetrahedron* 49, 6123). These conditions produced about 95% sulfurization as measured by HPLC analysis (Morvan et al., 1990 *Tetrahedron Letter* 31, 7149). This 5% contaminating oxidation could arise from the presence of oxygen dissolved in solvents and/or slow release of traces of iodine adsorbed on the inner surface of delivery lines during  
25 previous synthesis.

A major improvement is the use of an activating agent, 5-S-ethyltetrazole or 5-S-methyltetrazole at a concentration of 0.25 M for 5 min. Additionally, for those linkages which are phosphorothioate, the iodine solution is replaced with a 0.05 M solution of 3H-1,2-benzodithiole-3-one  
30 1,1-dioxide (Beaucage reagent) in acetonitrile. The delivery time for the sulfurization step is reduced to 5 seconds and the wait time is reduced to 300 seconds.

RNA synthesis is conducted on a 394 (ABI) synthesizer using a modified 2.5  $\mu$ mol scale protocol with a reduced 5 min coupling step for  
35 alkylsilyl protected RNA and 2.5 min coupling step for 2'-O-methylated RNA. A 6.5-fold excess (162.5  $\mu$ L of 0.1 M = 32.5  $\mu$ mol) of phosphoramidite

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and a 40-fold excess of *S*-ethyl tetrazole (400  $\mu$ L of 0.25 M = 100  $\mu$ mol) relative to polymer-bound 5'-hydroxyl was used in each coupling cycle. Average coupling yields on the 394 synthesizer, determined by colorimetric quantitation of the trityl fractions, was 97.5-99%. Other oligonucleotide synthesis reagents for the 394 synthesizer: detritylation solution was 2% TCA in methylene chloride; capping was performed with 16% *N*-Methyl imidazole in THF and 10% acetic anhydride/10% 2,6-lutidine in THF; oxidation solution was 16.9 mM  $I_2$ , 49 mM pyridine, 9% water in THF. Fisher Synthesis Grade acetonitrile was used directly from the reagent bottle. *S*-Ethyl tetrazole solution (0.25 M in acetonitrile) was made up from the solid obtained from Applied Biosystems. Sulfurizing reagent was obtained from Glen Research.

Average sulfurization efficiency (ASE) is determined using the formula:  $ASE = (PS/Total)^{1/n-1}$

where, PS = integrated  $^{31}P$  NMR values of the P=S diester

Total = integration value of all peaks

n = length of oligo

Referring to tables 42 and 43, effects of varying the delivery and the wait time for sulfurization with Beaucage's reagent is described. These data suggest that 5 second wait time and 300 second delivery time is the condition under which ASE is maximum.

Using the above conditions a 36 mer hammerhead ribozyme is synthesized which is targeted to site C. The ribozyme is synthesized to contain phosphorothioate linkages at four positions towards the 5' end. RNA cleavage activity of this ribozyme is shown in Fig. 16. Activity of the phosphorothioate ribozyme is comparable to the activity of a ribozyme lacking any phosphorothioate linkages.

Example 13: Protocol for the synthesis of 2'-N-phthalimido-nucleoside phosphoramidite

The 2'-amino group of a 2'-deoxy-2'-amino nucleoside is normally protected with N-(9-fluorenylmethoxycarbonyl) (Fmoc; Imazawa and Eckstein, 1979 *supra*; Pieken et al., 1991 *Science* 253, 314). This protecting group is not stable in  $CH_3CN$  solution or even in dry form during

prolonged storage at -20 °C. These problems need to be overcome in order to achieve large scale synthesis of RNA.

Applicant describes the use of alternative protecting groups for the 2'-amino group of 2'-deoxy-2'-amino nucleoside. Referring to Figure 17,  
5 phosphoramidite 17 was synthesized starting from 2'-deoxy-2'-aminonucleoside (12) using transient protection with Markevich reagent (Markiewicz *J. Chem. Res.* 1979, S, 24). An intermediate 13 was obtained in 50% yield, however subsequent introduction of N-phthaloyl (Pht) group by Nefken's method (Nefkens, 1960 *Nature* 185, 306), desilylation (15),  
10 dimethoxytrytilation (16) and phosphitylation led to phosphoramidite 17. Since overall yield of this multi-step procedure was low (20%) applicant investigated some alternative approaches, concentrating on selective introduction of N-phthaloyl group without acylation of 5' and 3' hydroxyls.

When 2'-deoxy-2'-amino-nucleoside was reacted with 1.05  
15 equivalents of Nefkens reagent in DMF overnight with subsequent treatment with Et<sub>3</sub>N (1 hour) only 10-15% of N and 5'(3')-bis-phthaloyl derivatives were formed with the major component being N-Pht-derivative 15. The N,O-bis by-products could be selectively and quantitatively converted to N-Pht derivative 15 by treatment of crude reaction mixture  
20 with cat. KCN/MeOH.

A convenient "one-pot" procedure for the synthesis of key intermediate 16 involves selective N-phthaloylation with subsequent dimethoxytrytilation by DMTC/Et<sub>3</sub>N and resulting in the preparation of DMT derivative 16 in 85% overall yield as follows. Standard phosphitylation of  
25 16 produced phosphoramidite 17 in 87% yield. One gram of 2'-amino nucleoside, for example 2'-amino uridine (US Biochemicals® part # 77140) was co-evaporated twice from dry dimethyl formamide (DMF) and dried in vacuo overnight. 50 mls of Aldrich sure-seal DMF was added to the dry 2'-amino uridine via syringe and the mixture was stirred for 10 minutes  
30 to produce a clear solution. 1.0 grams (1.05 eq.) of N-carbethoxyphthalimide (Nefken's reagent, 98% Janssen Chimica) was added and the solution was stirred overnight. Thin layer chromatography (TLC) showed 90% conversion to a faster moving products (10% ETOH in CHCl<sub>3</sub>) and 57 µl of TEA (0.1 eq.) was added to effect closure of the  
35 phthalimide ring. After 1 hour an additional 855 µl (1.5 eq.) of TEA was added followed by the addition of 1.53 grams (1.1 eq.) of DMT-Cl

(Lancaster Synthesis®, 98%). The reaction mixture was left to stir overnight and quenched with ETOH after TLC showed greater than 90% desired product. Dmf was removed under vacuum and the mixture was washed with sodium bicarbonate solution (5% aq., 500 mls) and extracted with ethyl acetate (2x 200 mls). A 25mm x 300mm flash column (75 grams Merck flash silica) was used for purification. Compound eluted at 80 to 85% ethyl acetate in hexanes (yield: 80% purity: >95% by <sup>1</sup>HNMR). Phosphoramidites were then prepared using standard protocols described above.

- 10 With phosphoramidite 17 in hand applicant synthesized several ribozymes with 2'-deoxy-2'-amino modifications. Analysis of the synthesis demonstrated coupling efficiency in 97-98% range. RNA cleavage activity of ribozymes containing 2'-deoxy-2'-amino-U modifications at U4 and/or U7 positions (see Figure 1), wherein the 2'-amino positions were either  
15 protected with Fmoc or Pht, was identical. Additionally, complete deprotection of 2'-deoxy-2'-amino-Uridine was confirmed by base-composition analysis. The coupling efficiency of phosphoramidite 17 was not effected over prolonged storage (1-2 months) at low temperatures.

#### Protecting 2' Position with a SEM Group

- 20 There follows a method using the 2'-(trimethylsilyl)ethoxymethyl protecting group (SEM) in the synthesis of oligoribonucleotides, and in particular those enzymatic molecules described above. For the synthesis of RNA it is important that the 2'-hydroxyl protecting group be stable throughout the various steps of the synthesis and base deprotection. At the  
25 same time, this group should also be readily removed when desired. To that end the *t*-butyldimethylsilyl group has been efficacious (Usman,N.; Ogilvie,K.K.; Jiang,M.-Y.; Cedergren,R.J. *J. Am. Chem. Soc.* 1987, 109, 7845-7854 and Scaringe,S.A.; Franklyn,C.; Usman,N. *Nucl. Acids Res.* 1990, 18, 5433-5441). However, long exposure times to tetra-*n*-  
30 butylammonium fluoride (TBAF) are generally required to fully remove this protecting group from the 2'-hydroxyl. In addition, the bulky alkyl substituents can prove to be a hindrance to coupling thereby necessitating longer coupling times. Finally, it has been shown that the TBDMS group is base labile and is partially deprotected during treatment with ethanolic  
35 ammonia (Scaringe,S.A.; Franklyn,C.; Usman,N. *Nucl. Acids Res.* 1990,

18, 5433-5441 and Stawinski, J.; Stromberg, R.; Thelin, M.; Westman, E. *Nucleic Acids Res.* 1988, 16, 9285-9298).

5 The (trimethylsilyl)ethoxymethyl ether (SEM) seems a suitable substitute. This protecting group is stable to base and all but the harshest acidic conditions. Therefore it is stable under the conditions required for oligonucleotide synthesis. It can be readily introduced and the oxygen carbon bond makes it unable to migrate. Finally, the SEM group can be removed with  $\text{BF}_3 \cdot \text{OEt}_2$  very quickly.

10 There follows a method for synthesis of RNA by protecting the 2'-position of a nucleotide during RNA synthesis with a (trimethylsilyl)ethoxymethyl (SEM) group. The method can involve use of standard RNA synthesis conditions as discussed below, or any other equivalent steps. Those in the art are familiar with such steps. The nucleotide used can be any normal nucleotide or may be substituted in  
15 various positions by methods well known in the art, e.g., as described by Eckstein *et al.*, *International Publication* No. WO 92/07065, Perrault *et al.*, *Nature* 1990, 344, 565-568, Pieken *et al.*, *Science* 1991, 253, 314-317, Usman, N.; Cedergren, R.J. *Trends in Biochem. Sci.* 1992, 17, 334-339, Usman *et al.*, PCT WO93/15187, and Sproat, B. *European Patent*  
20 *Application* 92110298.4.

This invention also features a method for covalently linking a SEM group to the 2'-position of a nucleotide. The method involves contacting a nucleoside with an SEM-containing molecule under SEM bonding conditions. In a preferred embodiment, the conditions are dibutyltin oxide,  
25 tetrabutylammonium fluoride and SEM-Cl. Those in the art, however, will recognize that other equivalent conditions can also be used.

In another aspect, the invention features a method for removal of an SEM group from a nucleoside molecule or an oligonucleotide. The method involves contacting the molecule or oligonucleotide with boron trifluoride etherate ( $\text{BF}_3 \cdot \text{OEt}_2$ ) under SEM removing conditions, e.g., in acetonitrile.  
30

Referring to Figure 18, there is shown the method for solid phase synthesis of RNA. A 2',5'-protected nucleotide is contacted with a solid phase bound nucleotide under RNA synthesis conditions to form a dinucleotide. The protecting group (R) at the 2'-position in prior art

methods can be a silyl ether, as shown in the Figure. In the method of the present invention, an SEM group is used in place of the silyl ether. Otherwise RNA synthesis can be performed by standard methodology.

Referring to Figure 19, there is shown the synthesis of 2'-O-SEM protected nucleosides and phosphoramidites. Briefly, a 5'-protected nucleoside (1) is protected at the 2'- or 3'-position by contacting with a derivative of SEM under appropriate conditions. Specifically, those conditions include contacting the nucleoside with dibutyltin oxide and SEM chloride. The 2 regioisomers are separated by chromatography and the 2'-protected moiety is converted into a phosphoramidite by standard procedure. The 3'-protected nucleoside is converted into a succinate derivative suitable for derivatization of a solid support.

Referring to Figure 20, a prior art method for deprotection of RNA using silyl ethers is shown. This contrasts with the method shown in Figure 21 in which deprotection of RNA containing an SEM group is performed. In step 1, the base protecting groups and cyanoethyl groups are removed by standard procedure. The SEM group is then removed as shown in the Figure. The details of the synthesis of phosphoramidites and SEM protected nucleosides and their use in synthesis of oligonucleotides and subsequent deprotection of

Example 14: Synthesis of 2'-O-((trimethylsilyl)ethoxymethyl)-5'-O-Dimethoxytrityl Uridine (2)

Referring to Figure 19, 5'-O-dimethoxytrityl uridine **1** (1.0 g, 1.83 mmol) in CH<sub>3</sub>CN (18 mL) was added dibutyltin oxide (1.0 g, 4.03 mmol) and TBAF (1 M, 2.38 mL, 2.38 mmol). The mixture was stirred for 2 h at RT (about 20-25°C) at which time (trimethylsilyl)ethoxymethyl chloride (SEM-Cl) (487 µL, 2.75 mmol) was added. The reaction mixture was stirred overnight and then filtered and evaporated. Flash chromatography (30% hexanes in ethyl acetate) yielded 347 mg (28.0%) of 2'-hydroxyl protected nucleoside **2** and 314 mg (25.3%) of 3'-hydroxyl protected nucleoside **3**.

Example 15: Synthesis of 2'-O-((trimethylsilyl)ethoxymethyl) Uridine (4)

Nucleoside **2** was detritylated following standard methods, as shown in Figure 19.

Example 16: Synthesis of 2'-O-((trimethylsilyl)ethoxymethyl)-5',3'-O-Acetyl Uridine (5)

Nucleoside 4 was acetylated following standard methods, as shown in Figure 19.

5 Example 17: Synthesis of 5',3'-O-Acetyl Uridine (6)

Referring to Figure 19, the fully protected uridine 5 (32 mg, 0.07 mmol) was dissolved in CH<sub>3</sub>CN (700 µL) and BF<sub>3</sub>•OEt<sub>2</sub> (17.5 µL, 0.14 mmol) was added. The reaction was stirred 15 m and MeOH was added to quench the reaction. Flash chromatography (5% MeOH in CH<sub>2</sub>Cl<sub>2</sub>) gave  
10 20 mg (88%) of SEM deprotected nucleoside 6.

Example 18: Synthesis of 2'-O-((trimethylsilyl)ethoxymethyl)-3'-O-Succinyl-5'-O-Dimethoxytrityl Uridine (2)

Nucleoside 3 was succinylated and coupled to the support following standard procedures, as shown in Figure 19.

15 Example 19: Synthesis of 2'-O-((trimethylsilyl)ethoxymethyl)-5'-O-Dimethoxytrityl Uridine 3'-(2-Cyanoethyl N,N-diisopropylphosphoramidite) (8)

Nucleoside 3 was phosphitylated following standard methods, as shown in Figure 19.

20 Example 20: Synthesis of RNA Using 2'-O-SEM Protection

Referring to Figure 18, the method of synthesis used follows the general procedure for RNA synthesis as described in Usman, N.; Ogilvie, K.K.; Jiang, M.-Y.; Cedergren, R.J. *J. Am. Chem. Soc.* 1987, 109, 7845-7854 and in Scaringe, S.A.; Franklyn, C.; Usman, N. *Nucl. Acids Res.* 1990, 18, 5433-5441. The phosphoramidite 8 was coupled following  
25 standard RNA methods to provide a 10-mer of uridylic acid. Syntheses were conducted on a 394 (ABI) synthesizer using a modified 2.5 µmol scale protocol with a 10 m coupling step. A thirteen-fold excess (325 µL of 0.1 M = 32.5 µmol) of phosphoramidite and a 80-fold excess of tetrazole  
30 (400 µL of 0.5 M = 200 µmol) relative to polymer-bound 5'-hydroxyl was used in each coupling cycle. Average coupling yields on the 394, determined by colorimetric quantitation of the trityl fractions, were 98-99%. Other oligonucleotide synthesis reagents for the 394: Detritylation solution was 2% TCA in methylene chloride; capping was performed with 16% N-



Methyl imidazole in THF and 10% acetic anhydride/10% 2,6-lutidine in THF; oxidation solution was 16.9 mM I<sub>2</sub>, 49 mM pyridine, 9% water in THF. Fisher Synthesis Grade acetonitrile was used directly from the reagent bottle.

- 5 Referring to Figure 21, the homopolymer was base deprotected with NH<sub>3</sub>/EtOH at 65 °C. The solution was decanted and the support was washed twice with a solution of 1:1:1 H<sub>2</sub>O:CH<sub>3</sub>CN:MeOH. The combined solutions were dried down and then diluted with CH<sub>3</sub>CN (1 mL). BF<sub>3</sub>•OEt<sub>2</sub> (2.5 μL, 30 μmol) was added to the solution and aliquots were removed at  
10 ten time points. The results indicate that after 30 min deprotection is complete, as shown in Figure 22.

### III. Vectors Expressing Ribozymes

- There follows a method for expression of a ribozyme in a bacterial or eucaryotic cell, and for production of large amounts of such a ribozyme. In  
15 general, the invention features a method for preparing multi-copy cassettes encoding a defined ribozyme structure for production of a ribozyme at a decreased cost. A vector is produced which encodes a plurality of ribozymes which are cleaved at their 3' and 5' ends from an RNA transcript produced from the vector by only one other ribozyme. The system is useful  
20 for scaling up production of a ribozyme, which may be either modified or unmodified, *in situ* or *in vitro*. Such vector systems can be used to express a desired ribozyme in a specific cell, or can be used in an *in vitro* system to allow production of large amounts of a desired ribozyme. The vectors of this invention allow a higher yield synthesis of a ribozyme in the form of an  
25 RNA transcript which is cleaved *in situ* or *in vitro* before or after transcript isolation.

- Thus, this invention is distinct from the prior art in that a single ribozyme is used to process the 3' and 5' ends of each therapeutic, trans-acting or desired ribozyme instead of processing only one end, or only one  
30 ribozyme. This allows smaller vectors to be derived with multiple trans-acting ribozymes released by only one other ribozyme from the mRNA transcript. Applicant has also provided methods by which the activity of such ribozymes is increased compared to those in the art, by designing ribozyme-encoding vectors and the corresponding transcript such that

folding of the mRNA does not interfere with processing by the releasing ribozyme.

The stability of the ribozyme produced in this method can be enhanced by provision of sequences at the termini of the ribozymes as described by Draper et al., PCT WO 93/23509, hereby incorporated by reference herein.

The method of this invention is advantageous since it provides high yield synthesis of ribozymes by use of low cost transcription-based protocols, compared to existing chemical ribozyme synthesis, and can use isolation techniques currently used to purify chemically synthesized oligonucleotides. Thus, the method allows synthesis of ribozymes in high yield at low cost for analytical, diagnostic, or therapeutic applications.

The method is also useful for synthesis of ribozymes *in vitro* for ribozyme structural studies, enzymatic studies, target RNA accessibility studies, transcription inhibition studies and nuclease protection studies, much is described by Draper et al., PCT WO 93/23509 hereby incorporated by reference herein.

The method can also be used to produce ribozymes *in situ* either to increase the intracellular concentration of a desired therapeutic ribozyme, or to produce a concatameric transcript for subsequent *in vitro* isolation of unit length ribozyme. The desired ribozyme can be used to inhibit gene expression in molecular genetic analyses or in infectious cell systems, and to test the efficacy of a therapeutic molecule or treat afflicted cells.

Thus, in general, the invention features a vector which includes a bacterial, viral or eucaryotic promoter within a plasmid, cosmid, phagmid, virus, viroid, virusoid or phage vector. Other vectors are equally suitable and include double-stranded, or partially double-stranded DNA, formed by an amplification method such as the polymerase chain reaction, or double-stranded, partially double-stranded or single-stranded RNA, formed by site-directed homologous recombination into viral or viroid RNA genomes. Such vectors need not be circular. Transcriptionally linked to the promoter region is a first ribozyme-encoding region, and nucleotide sequences encoding a ribozyme cleavage sequence which is placed on either side of a region encoding a therapeutic or otherwise desired second ribozyme.

Suitable restriction endonuclease sites can be provided to ease construction of this vector in DNA vectors or in requisite DNA vectors of an RNA expression system. The desired second ribozyme may be any desired type of ribozyme, such as a hammerhead, hairpin, hepatitis delta virus (HDV) or other catalytic center, and can include group I and group II introns, as discussed above. The first ribozyme is chosen to cleave the encoded cleavage sequence, and may also be any desired ribozyme, for example, a *Tetrahymena* derived ribozyme, which may, for example, include an imbedded restriction endonuclease site in the center of a self-recognition sequence to aid in vector construction. This endonuclease site is useful for construction of the vector, and subsequent analysis of the vector.

When the promoter of such a vector is activated an RNA transcript is produced which includes the first and second ribozyme sequences. The first ribozyme sequence is able to act, under appropriate conditions, to cause cleavage at the cleavage sites to release the second ribozyme sequences. These second ribozyme sequences can then act at their target RNA sites, or can be isolated for later use or analysis.

Thus, in one aspect the invention features a vector which includes a first nucleic acid sequence (encoding a first ribozyme having intramolecular cleaving activity), and a second nucleic acid sequence (encoding a second ribozyme having intermolecular cleaving enzymatic activity) flanked by nucleic acid sequences encoding RNA which is cleaved by the first ribozyme to release the second ribozyme from the RNA transcript encoded by the vector. The second ribozyme may be flanked by the first ribozyme either on the 5' side or 3' side. If desired, the first ribozyme may be encoded on a separate vector and may have intermolecular cleaving activity.

As discussed above, the first ribozyme can be chosen to be any self-cleaving ribozyme, and the second ribozyme may be chosen to be any desired ribozyme. The flanking sequences are chosen to include sequences recognized by the first ribozyme. When the vector is caused to express RNA from these nucleic acid sequences, that RNA has the ability under appropriate conditions to cleave each of the flanking regions and thereby release one or more copies of the second ribozyme. If desired, several different second ribozymes can be produced by the same vector, or

several different vectors can be placed in the same vessel or cell to produce different ribozymes.

In preferred embodiments, the vector includes a plurality of the nucleic acid sequences encoding the second ribozyme, each flanked by nucleic acid sequences recognized by the first ribozyme. Most preferably, such a plurality includes at least six to nine or even between 60 - 100 nucleic acid sequences. In other preferred embodiments, the vector includes a promoter which regulates expression of the nucleic acid encoding the ribozymes from the vector; and the vector is chosen from a plasmid, cosmid, phagmid, virus, viroid or phage. In a most preferred embodiment, the plurality of nucleic acid sequences are identical and are arranged in sequential order such that each has an identical end nearest to the promoter. If desired, a poly(A) sequence adjacent to the sequence encoding the first or second ribozyme may be provided to increase stability of the RNA produced by the vector; and a restriction endonuclease site adjacent to the nucleic acid encoding the first ribozyme is provided to allow insertion of nucleic acid encoding the second ribozyme during construction of the vector.

In a second aspect, the invention features a method for formation of a ribozyme expression vector by providing a vector including nucleic acid encoding a first ribozyme, as discussed above, and providing a single-stranded DNA encoding a second ribozyme, as discussed above. The single-stranded DNA is then allowed to anneal to form a partial duplex DNA which can be filled in by a treatment with an appropriate enzyme, such as a DNA polymerase in the presence of dNTPs, to form a duplex DNA which can then be ligated to the vector. Large vectors resulting from this method can then be selected to insure that a high copy number of the single-stranded DNA encoding the second ribozyme is incorporated into the vector.

In a further aspect, the invention features a method for production of ribozymes by providing a vector as described above, expressing RNA from that vector, and allowing cleavage by the first ribozyme to release the second ribozyme.

In preferred embodiments, three different ribozyme motifs are used as cis-cleaving ribozymes. The hammerhead, hairpin, and hepatitis delta

virus (HDV) ribozyme motifs consist of small, well-defined sequences that rapidly self-cleave *in vitro* (Symons, 1992 Annu. Rev. Biochem. 61, 641). While structural and functional differences exist among the three ribozyme motifs, they self-process efficiently *in vivo*. All three ribozyme motifs self-process to 87-95% completion in the absence of 3' flanking sequences. *In vitro*, the self-processing constructs described in this invention are significantly more active than those reported by Taira et al., 1990 supra; and Altschuler et al., 1992 Gene 122, 85. The present invention enables the use of cis-cleaving ribozymes to efficiently truncate RNA molecules at specific sites *in vivo* by ensuring lack of secondary structure which prevents processing.

#### Isolation of Therapeutic Ribozyme

The preferred method of isolating therapeutic ribozyme is by a chromatographic technique. The HPLC purification methods and reverse HPLC purification methods described by Draper et al., PCT WO 93/23509, hereby incorporated by reference herein, can be used. Alternatively, the attachment of complementary oligonucleotides to cellulose or other chromatography columns allows isolation of the therapeutic second ribozyme, for example, by hybridization to the region between the flanking arms and the enzymatic RNA. This hybridization will select against the short flanking sequences without the desired enzymatic RNA, and against the releasing first ribozyme. The hybridization can be accomplished in the presence of a chaotropic agent to prevent nuclease degradation. The oligonucleotides on the matrix can be modified to minimize nuclease activity, for example, by provision of 2'-O-methyl RNA oligonucleotides. Such modifications of the oligonucleotide attached to the column matrix will allow the multiple use of the column with minimal oligo degradation. Many such modifications are known in the art, but a chemically stable non-reducible modification is preferred. For example, phosphorothioate modifications can also be used.

The expressed ribozyme RNA can be isolated from bacterial or eucaryotic cells by routine procedures such as lysis followed by guanidine isothiocyanate isolation.

The current known self-cleaving site of *Tetrahymena* can be used in an alternative vector of this invention. If desired, the full-length

*Tetrahymena* sequence may be used, or a shorter sequence may be used. It is preferred that, in order to decrease the superfluous sequences in the self-cleaving site at the 5' cleavage end, the hairpin normally present in the *Tetrahymena* ribozyme should contain the therapeutic second ribozyme 3' sequence and its complement. That is, the first releasing ribozyme-encoding DNA is provided in two portions, separated by DNA encoding the desired second ribozyme. For example, if the therapeutic second ribozyme recognition sequence is CGGACGA/CGAGGA, then CGAGGA is provided in the self-cleaving site loop such that it is in a stem structure recognized by the *Tetrahymena* ribozyme. The loop of the stem may include a restriction endonuclease site into which the desired second ribozyme-encoding DNA is placed.

If desired, the vector may be used in a therapeutic protocol by use of the systems described by Lechner, PCT WO 92/13070, hereby incorporated by reference herein, to allow a timed expression of the therapeutic second ribozyme, as well as an appropriate shut off of cell or gene function. Thus, the vector will include a promoter which appropriately expresses enzymatically active RNA only in the presence of an RNA or another molecule which indicates the presence of an undesired organism or state. Such enzymatically active RNA will then kill or harm the cell in which it exists, as described by Lechner, *id.*, or act to cause reduced expression of a desired protein product.

A number of suitable RNA vectors may also be used in this invention. The vectors include plant viroids, plant viruses which contain single or double-stranded RNA genomes and animal viruses which contain RNA genomes, such as the picornaviruses, myxoviruses, paramyxoviruses, hepatitis A virus, reovirus and retroviruses. In many instances cited, use of these viral vectors also results in tissue specific delivery of the ribozymes.

#### Example 21: Design of self-processing cassettes

In a preferred embodiment, applicant compared the *in vitro* and *in vivo* cis-cleaving activity of three different ribozyme motifs—the hammerhead, the hairpin and the hepatitis delta virus ribozyme—in order to assess their potential to process the ends of transcripts *in vivo*. To make a direct comparison among the three, however, it is important to design the ribozyme-containing transcripts to be as similar as possible. To this end,

all the ribozyme cassettes contained the same trans-acting hammerhead ribozyme followed immediately by one of the three cis-acting ribozymes (Figure 23-25). For simplicity, applicant refers to each cassette by an abbreviation that indicates the downstream cis-cleaving ribozyme only.

5 Thus HH refers to the cis-cleaving cassette containing a hammerhead ribozyme, while HP and HDV refer to the cassettes containing hairpin and hepatitis delta virus cis-cleaving ribozymes, respectively. The general design of the ribozyme cassettes, as well as specific differences among the cassettes, are outlined below.

10 A sequence predicted to form a stable stem-loop structure is included at the 5' end of all the transcripts. The hairpin stem contains the T7 RNA polymerase initiation sequence (Milligan & Uhlenbeck, 1989 Methods Enzymol. 180, 51) and its complement, separated by a stable tetra-loop (Antao et al., 1991 Nucleic Acids Res. 19, 5901). By incorporating the T7  
15 initiation sequence into a stem-loop structure, applicant hoped to avoid nonproductive base pairing interactions with either the trans-acting ribozyme or with the cis-acting ribozyme. The presence of a hairpin at the end of a transcript may also contribute to the stability of the transcript *in vivo*. These are non-limiting examples. Those in the art will recognize that  
20 other embodiments can be readily generated using a variety of promoters, initiator sequences and stem-loop structure combinations generally known in the art.

The trans-acting ribozyme used in this study is targeted to a site B (5'...CUGGAGUC↓GACCUUC...3'). The 5' binding arm of the ribozyme, 5'-  
25 GAAGGUC-3', and the core of the ribozyme, 5'-CUGAUGAGGCCGAAAGGCCGAA-3', remain constant in all cases. In addition, all transcripts also contain a single nucleotide between the 5' stem-loop and the first nucleotide of the ribozyme. The linker nucleotide was required to obtain the same activity *in vitro* that was measured with an  
30 identical ribozyme lacking the 5' hairpin. Because the three cis-cleaving ribozymes have different requirements at the site of cleavage, slight differences were unavoidable at the 3' end of the processed transcript. The junction between the trans- and cis-acting ribozyme is, however, designed so that there is minimal extraneous sequence left at the 3' end of the trans-  
35 cleaving ribozyme once cis-cleavage occurs. The only differences between the constructs lie in the 3' binding arm of the ribozyme, where

either 6 or 7 nucleotides, 5'-ACUCCA(+/-G)-3', complementary to the target sequence are present and where, after processing, two to five extra nucleotides remain.

The cis-cleaving hammerhead ribozyme used in the HH cassette is based on the design of Grosshans and Cech, 1991 supra. As shown in Figure 23, the 3' binding arm of the trans-acting ribozyme is included in the required base-pairing interactions of the cis-cleaving ribozyme to form stem I. Two extra nucleotides, UC, were included at the end of the 3' binding arm to form the self-processing hammerhead ribozyme site (Ruffner et al., 1990 supra) which remain on the 3' end of the trans-acting ribozyme following self-processing.

The hairpin ribozyme portion of the HP self-processing construct is based on the minimal wild-type sequence (Hampel & Tritz, 1989 supra). A tetra-loop at the end of helix 1 (3' side of the cleavage site) serves to link the two portions and thus allows a minimal five nucleotides to remain at the end of the released trans-acting ribozyme following self-processing. Two variants of HP were designed: HP(GU) and HP(GC). The HP(GU) was constructed with a G-U wobble base pair in helix 2 (A52G substitution; Figure 24). This slight destabilization of helix 2 was intended to improve self-processing activity by promoting product release and preventing the reverse reaction (Berzal-Herranz et al., 1992 Genes & Dev. 6, 129; Chowrira et al., 1993 Biochemistry 32, 1088). The HP(GC) cassette was constructed as a control for strong base-pairing interactions in helix 2 (U77C and A52G substitution; Figure 24). Another modification to discourage the reverse ligation reaction of the hairpin ribozyme was to shorten helix 1 (Figure 24) by one base pair relative to the wild-type sequence (Chowrira & Burke, 1991 Biochemistry 30, 8518).

The HDV ribozyme self-processes efficiently when the nucleotide 5' to the cleavage site is a pyrimidine, and somewhat less so when adenosine is in that position. No other sequence requirements have been identified upstream of the cleavage site, however, we have observed some decrease in activity when a stem-loop structure was present within 2 nt of the cleavage site. The HDV self-processing construct (Fig 25) was designed to generate the trans-acting hammerhead ribozyme with only two additional nucleotides at its 3' end after self-processing. The HDV sequence used here is based on the anti-genomic sequence (Perrota & Been, 1992 supra)



but includes the modifications of Been et al., 1992 (Biochemistry 31, 11843) in which cis-cleavage activity of the ribozyme was improved by the substitution of a shortened helix 4 for a wild-type stem-loop (Figure 25).

To prepare DNA inserts that encode self-processing ribozyme cassettes, partially overlapping top- and bottom-strand oligonucleotides (60-90 nucleotides) were designed to include sequences for the T7 promoter, the trans-acting ribozyme, the cis-cleaving ribozyme and appropriate restriction sites for use in cloning (see Fig. 26). The single-strand portions of annealed oligonucleotides were converted to double-strands using Sequenase® (U.S. Biochemicals). Insert DNA was ligated into *EcoRI/HindIII*-digested puc18 and transformed into *E. coli* strain DH5α using standard protocols (Maniatis et al., 1982 in Molecular Cloning Cold Spring Harbor Press). The identity of positive clones was confirmed by sequencing small-scale plasmid preparations.

Larger scale preparations of plasmid DNA for use as *in vitro* transcription templates and in transactions were prepared using the protocol and columns from QIAGEN Inc. (Studio City, CA) except that an additional ethanol precipitation was included as the final step.

#### Example 22: RNA Processing *in vitro*

Transcription reactions containing linear plasmid templates were carried out essentially as described (Milligan & Uhlenbeck, 1989 Supra; Chowrira & Burke, 1991 Supra). In order to prepare 5' end-labeled transcripts, standard transcription reactions were carried out in the presence of 10-20 μCi [ $\gamma$ -<sup>32</sup>P]GTP, 200 μM each NTP and 0.5 to 1 μg of linearized plasmid template. The concentration of MgCl<sub>2</sub> was maintained at 10 mM above the total nucleotide concentration.

To compare the ability of the different ribozyme cassettes to self-process *in vitro*, each construct was transcribed and allowed to undergo self-processing under identical conditions at 37°C. For these comparisons, equal amounts of linearized DNA templates bearing the various ribozyme cassettes were transcribed in the presence of [ $\gamma$ -<sup>32</sup>P]GTP to generate 5' end-labeled transcripts. In this manner only the full-length, unprocessed transcripts and the released trans-ribozymes are visualized by autoradiography. In all reactions, Mg<sup>2+</sup> was included at 10 mM above the nucleotide concentration so that cleavage by all the ribozyme cassettes

would be supported. Transcription templates were linearized at several positions by digestion with different restriction enzymes so that self-processing in the presence of increasing lengths of downstream sequence could be compared (see Fig. 26). The resulting transcripts have either 4-5  
5 non-ribozyme nucleotides at the 3' end (*Hind*III-digested template), 220 nucleotides (*Nde*I digested templates) or 454 nucleotides of downstream sequence (*Rca*I digested template).

As shown in Figure 27, all four ribozyme cassettes are capable of self-processing and yield RNA products of expected sizes. Two nucleotides  
10 essential for hammerhead ribozyme activity (Ruffner et al., 1990 *supra*) have been changed in the HH(mutant) core sequence (see Figure 23) and so this transcript is unable to undergo self-processing (Fig. 27). This is evidenced by the lack of a released 5' RNA in the HH(mutant), although the full-length RNAs are present. Comparison of the amounts of released  
15 trans-ribozyme (Fig. 27) indicate that there are differences in the ability of these ribozymes to self-process *in vitro*, especially with respect to the presence of downstream sequence. For the two HP constructs, it is clear that HP(GC) is more efficient than the HP(GU) ribozyme, both in the presence and in the absence of extra downstream sequence. In addition,  
20 the activity of HP(GU) falls off more dramatically when downstream sequence is present. The stronger G:C base pair likely contributes to the HP(GC) construct's ability to fold correctly (and/or more quickly) into the productive structure, even when as much as 216 extra nucleotides are present downstream. The HH ribozyme construct is also quite efficient at  
25 self-processing, and slightly better than the HP(GU) construct even when downstream sequence is present.

Of the three ribozyme motifs, the presence of extra downstream sequence seems to most affect the efficiency of HDV. When no extra sequence is present downstream, HDV is quite efficient and self-processes  
30 to approximately the same level as the HH and HP(GC) cassettes. However, when extra downstream sequence is present, the self-processing activity seems to decrease almost as dramatically as is seen with the (sub-optimal) HP(GU) cassette.

Example 23: Kinetics of self-processing reaction

*Hind*III-digested template (250 ng) was used in a standard transcription reaction mixture containing: 50 mM Tris-HCl pH 8.3; 1 mM ATP, GTP and UTP; 50  $\mu$ M CTP; 40  $\mu$ Ci [ $\alpha$ -<sup>32</sup>P]CTP; 12 mM MgCl<sub>2</sub>; 10 mM DTT. The transcription/self-processing reaction was initiated by the addition of T7 RNA polymerase (15 U/ $\mu$ l). Aliquots of 5  $\mu$ l were taken at regular time intervals and the reaction was stopped by adding an equal volume of 2x formamide loading buffer (95% formamide, 15 mM EDTA, & dyes) and freezing on dry ice. The samples were resolved on a 10% polyacrylamide sequencing gel and results were quantitated by PhosphorImager (Molecular Dynamics, Sunnyvale, CA). Ribozyme self-cleavage rates were determined from non-linear, least-squares fits (KaleidaGraph, Synergy Software, Reading, PA) of the data to the equation:

$$(\text{Fraction Uncleaved Transcript}) = \frac{1}{k} (1 - e^{-kt})$$

where *t* represents time and *k* represents the unimolecular rate constant for cleavage (Long & Uhlenbeck, 1994 Proc. Natl. Acad. Sci. USA 91, 6977).

Linear templates were prepared by digesting the plasmids with *Hind*III so that transcripts will contain only four to five vector-derived nucleotides at the 3' end (see Figure 23-25). By comparison of the unimolecular rate constant (*k*) determined for each construct, it is clear that HH is the most efficient at self-processing (Table 44). The HH transcript self-processes 2-fold faster than HDV and 3-fold faster than HP(GC) transcripts. Although the HP(GU) RNA undergoes self-processing, it is at least 6-fold slower than the HP(GC) construct. This is consistent with previous observations that the stability of helix 2 is essential for self-processing and trans-cleavage activity of the hairpin ribozyme (Hampel et al., 1990 supra; Chowrira & Burke, 1991 supra). The rate of HH self-cleavage during transcription measured here (1.2 min<sup>-1</sup>) is similar to the rate measured by Long and Uhlenbeck 1994 supra using a HH that has a different stem I and stem III. Self-processing rates during transcription for HP and HDV have not been previously reported. However, self-processing of the HDV ribozyme—as measured here during transcription—is significantly slower than when tested after isolation from a denaturing gel (Been et al., 1992 supra). This decrease likely reflects the difference in protocol as well as the presence of 5' flanking sequence in the HDV construct used here.

Example 24: Effect of downstream sequences on trans-cleavage *in vitro*

Transcripts containing the trans ribozyme with or without 3' flanking sequences were assayed for their ability to cleave their target *in trans*. To this end, transcripts from three templates were resolved on a preparative gel and bands corresponding both to processed trans-acting ribozymes from the HH transcription reaction, and to full-length HH(mutant) and  $\Delta$ HDV transcripts were isolated. In all three transcripts the trans-acting ribozyme portion is identical—with the exception of sequences at their 3' ends. The HH trans-acting ribozyme contains only an additional UC at its 3' end, while HH(mutant) and  $\Delta$ HDV have 52 and 37 nucleotides, respectively, at their 3' ends. A 622 nucleotide, internally-labeled target RNA was incubated, under ribozyme excess conditions, along with the three ribozyme transcripts in a standard reaction buffer.

To make internally-labeled substrate RNA for trans-ribozyme cleavage reactions, a 622 nt region (containing hammerhead site P) was synthesized by PCR using primers that place the T7 RNA promoter upstream of the amplified sequence. Target RNA was transcribed in a standard transcription buffer in the presence of [ $\alpha$ - $^{32}$ P]CTP (Chowrira & Burke, 1991 *supra*). The reaction mixture was treated with 15 units of ribonuclease-free DNaseI, extracted with phenol followed by chloroform:isoamyl alcohol (25:1), precipitated with isopropanol and washed with 70% ethanol. The dried pellet was resuspended in 20  $\mu$ l DEPC-treated water and stored at -20°C.

Unlabeled ribozyme (1 $\mu$ M) and internally labeled 622 nt substrate RNA (<10 nM) were denatured and renatured separately in a standard cleavage buffer (containing 50 mM Tris-HCl pH 7.5 and 10 mM MgCl<sub>2</sub>) by heating to 90°C for 2 min. and slow cooling to 37°C for 10 min. The reaction was initiated by mixing the ribozyme and substrate mixtures and incubating at 37°C. Aliquots of 5  $\mu$ l were taken at regular time intervals, quenched by adding an equal volume of 2X formamide gel loading buffer and frozen on dry ice. The samples were resolved on 5% polyacrylamide sequencing gel and results were quantitatively analyzed by radioanalytic imaging of gels with a PhosphorImager<sup>®</sup> (Molecular Dynamics, Sunnyvale, CA).

The HH trans-acting ribozyme cleaves the target RNA approximately 10-fold faster than the  $\Delta$ HDV transcript and greater than 20-fold faster than

the HH(mutant) transcript (Figure 28). The additional nucleotides at the end of HH(mutant) form 7 base-pairs with the 3' target-binding arm of the trans-acting ribozyme (Figure 23). This interaction must be disrupted (at a cost of 6 kcal/mole) to make the trans-acting ribozyme available for binding the target sequence. In contrast, the additional nucleotides at the end of  $\Delta$ HDV were not designed to form any strong, alternative base-pairing with the trans-ribozyme. Nevertheless, the  $\Delta$ HDV sequences are predicted to form multiple structures involving the 3' target-binding arm of the trans ribozyme that have stabilities ranging from 1-2 kcal/mole. Thus, the observed reductions in activity for the  $\Delta$ HDV and HH(mutant) constructs are consistent with the predicted folded structures, and it reinforces the view that the flanking sequences can decrease the catalytic efficiency of a ribozyme through nonproductive interactions with either the ribozyme or the substrate or both.

15 Example 25: RNA self-processing *in vivo*

Since three of the constructs (HH, HDV and HP(GC)) self-process efficiently in solution, the affect of the mammalian cellular milieu on ribozyme self-processing was next explored by applicant. A transient expression system was employed to investigate ribozyme activity *in vivo*. A mouse cell line (OST7-1) that constitutively expresses T7 RNA polymerase in the cytoplasm was chosen for this study (Elroy-Stein and Moss, 1990 Proc. Natl. Acad. Sci. USA 87, 6743). In these cells plasmids containing a ribozyme cassette downstream of the T7 promoter will be transcribed efficiently in the cytoplasm (Elroy-Stein & Moss, 1990 supra).

25 Monolayers of a mouse L9 fibroblast cell line (OST7-1; Elroy-Stein and Moss, 1990 supra) were grown in 6-well plates with  $\sim 5 \times 10^5$  cells/well. Cells were transfected with circular plasmids (5  $\mu$ g/well) using the calcium phosphate-DNA precipitation method (Maniatis et al., 1982 supra). Cells were lysed (4 hours post-transfection) by the addition of standard lysis buffer (200  $\mu$ l/well) containing 4M guanadinium isothiocyanate, 25 mM sodium citrate (pH 7.0), 0.5% sarkosyl (Chomczynski and Sacchi, 1987 Anal. Biochem. 162, 156), and 50 mM EDTA pH 8.0. The lysate was extracted once with water-saturated phenol followed by one extraction with chloroform:isoamyl alcohol (25:1). Total cellular RNA was precipitated with 30 an equal volume of isopropanol. The RNA pellet was resuspended in 0.2 35

M ammonium acetate and reprecipitated with ethanol. The pellet was then washed with 70% ethanol and resuspended in DEPC-treated water.

Purified cellular RNA (3 µg/reaction) was first denatured in the presence of a 5' end-labeled DNA primer (100 pmol) by heating to 90°C for 2 min. in the absence of Mg<sup>2+</sup>, and then snap-cooling on ice for at least 15 min. This protocol allows for efficient annealing of the primer to its complementary RNA sequence. The primer was extended using Superscript II reverse transcriptase (8 U/µl; BRL) in a buffer containing 50 mM Tris-HCl pH 8.3; 10 mM DTT; 75 mM KCl; 1 mM MgCl<sub>2</sub>; 1 mM each dNTP. The extension reaction was carried out at 42°C for 10 min. The reaction was terminated by adding an equal volume of 2x formamide gel loading buffer and freezing on crushed dry ice. The samples were resolved on a 10% polyacrylamide sequencing gel. The primer sequences are as follows: HH primer, 5'-CTCCAGTTTCGAGCTTT-3'; HDV primer, 5'-AAGTAGCCCAGGTCGGACC-3'; HP primer, 5'-ACCAGGTAATATACCACAAC-3'.

As shown in Figure 29, specific bands corresponding to full-length precursor RNA and 3' cleavage products were detected from cells transfected with the self-processing cassettes. All three constructs, in addition to being transcriptionally active, appear to self-process efficiently in the cytoplasm of OST7-1 cells. In particular, the HH and HP(GC) constructs self-process to greater than 95%. The overall extent of self-processing in OST7-1 cells appears to be strikingly similar to the extent of self-processing *in vitro* (Figure 29 "In Vitro +MgCl<sub>2</sub>" vs. "Cellular").

Consistent with the *in vitro* self-processing results, the HP(GU) cassette self-processed to approximately 50% in OST7-1 cells. As expected, transfection with plasmids containing the HH(mutant) cassette yielded a primer-extension product corresponding to the full-length RNA with no detectable cleavage products (Figure 29). The latter result strongly suggests that the primer extension band corresponding to the 3' cleavage product is not an artifact of reverse transcription.

Applicant was concerned with the possibility that RNA self-processing might occur during cell lysis, RNA isolation and /or the primer extension assay. Two precautions were taken to exclude this possibility. First, 50 mM EDTA was included in the lysis buffer. EDTA is a strong chelator of divalent

metal ions such as  $Mg^{2+}$  and  $Ca^{2+}$  that are necessary for ribozyme activity. Divalent metal ions are therefore unavailable to self-processing RNAs following cell lysis. A second precaution involved using primers in the primer-extension assay that were designed to hybridize to essential regions of the processing ribozyme. Binding of these primers should prevent the 3' cis-acting ribozymes from folding into the conformation essential for catalytic activity.

Two experiments were carried out to further eliminate the possibility that self-processing is occurring either during RNA preparations or during the primer extension analysis. The first experiment involves primer extension analysis on full-length precursor RNAs that were added to non-transfected OST7-1 lysates after cell lysis. Thus, only if self-processing is occurring at some point after lysis would cleavage products be detected. Full-length precursor RNAs were prepared by transcribing under conditions of low  $Mg^{2+}$  (5 mM) and high NTP concentration (total 12 mM) in an attempt to eliminate the free  $Mg^{2+}$  required for the self-processing reaction (Michel et al. 1992 *Genes & Dev.* 6, 1373). The full-length precursor RNAs were gel-purified, and a known amount was added to lysates of non-transfected OST7-1 cells. RNA was purified from these lysates and incubated for 1 hr in DEPC-treated water at 37° C prior to the standard primer extension analysis (Figure 29, *in vitro* "-MgCl<sub>2</sub>" control). The predominant RNA detected in all cases corresponds to the primer extension product of full-length precursor RNAs. If, instead, the purified RNA containing the full-length precursor is incubated in 10 mM MgCl<sub>2</sub> prior to the primer extension analysis, most or all of the RNA detected by primer extension analysis undergoes cleavage (Figure 29, *in vitro* "+MgCl<sub>2</sub>" control). These results indicate that the standard RNA isolation and primer extension protocols used here do not provide a favorable environment for RNA self-processing, even though the RNA in question is inherently able to undergo self-cleavage.

In a second experiment to demonstrate lack of self-processing during work up, internally-labeled precursor RNAs were prepared and added to non-transfected OST7-1 lysates as in the previous control. The internally-labeled precursor RNAs were carried through the RNA purification and primer extension reactions (in the presence of unlabeled primers) and analyzed to determine the extent of self-processing. By this analysis, the

vast majority of the added full-length RNA remained intact during the entire process of RNA isolation and primer extension.

- These two control experiments validate the protocols used and support applicant's conclusion that the self-processing reactions catalyzed by HH, HDV and HP(GC) cassettes are occurring in the cytoplasm of OST7-1 cells.

Sequences in figures 23 through 25 are meant to be non-limiting examples. Those in the art will recognize that other embodiments can be readily generated using techniques generally known in the art.

- In addition, those in the art will recognize that Applicant provides guidance through the above examples as to how to best design vectors of this invention so that secondary structure of the mRNA allows efficient cleavage by releasing ribozymes. Thus, the specific constructs are not limiting in this invention. Such constructs can be readily tested as described above for such secondary structure, either by computer folding algorithms or empirically. Such constructs will then allow at least 80% completion of release of ribozymes, which can be readily determined as described above or by methods known in the art. That is, any such secondary structure in the RNA does not reduce release of the ribozymes by more than 20%.

#### IV. Ribozymes Expressed by RNA Polymerase III

- Applicant has determined that the level of production of a foreign RNA, using a RNA polymerase III (pol III) based system, can be significantly enhanced by ensuring that the RNA is produced with the 5' terminus and a 3' region of the RNA molecule base-paired together to form a stable intramolecular stem structure. This stem structure is formed by hydrogen bond interactions (either Watson-Crick or non-Watson-Crick) between nucleotides in the 3' region (at least 8 bases) and complementary nucleotides in the 5' terminus of the same RNA molecule.

- Although the example provided below involves a type 2 pol III gene unit, a number of other pol III promoter systems can also be used, for example, tRNA (Hall et al., 1982 *Cell* 29, 3-5), 5S RNA (Nielsen et al., 1993, *Nucleic Acids Res.* 21, 3631-3636), adenovirus VA RNA (Fowlkes and Shenk, 1980 *Cell* 22, 405-413), U6 snRNA (Gupta and Reddy, 1990



*Nucleic Acids Res.* 19, 2073-2075), vault RNA (Kickoefer et al., 1993 *J. Biol. Chem.* 268, 7868-7873), telomerase RNA (Romero and Blackburn, 1991 *Cell* 67, 343-353), and others.

5 The construct described in this invention is able to accumulate RNA to a significantly higher level than other constructs, even those in which 5' and 3' ends are involved in hairpin loops. Using such a construct the level of expression of a foreign RNA can be increased to between 20,000 and 50,000 copies per cell. This makes such constructs, and the vectors encoding such constructs, excellent for use in decoy, therapeutic editing  
10 and antisense protocols as well as for ribozyme formation. In addition, the molecules can be used as agonist or antagonist RNAs (affinity RNAs). Generally, applicant believes that the intramolecular base-paired interaction between the 5' terminus and the 3' region of the RNA should be in a double-stranded structure in order to achieve enhanced RNA  
15 accumulation.

Thus, in one preferred embodiment the invention features a pol III promoter system (e.g., a type 2 system) used to synthesize a chimeric RNA molecule which includes tRNA sequences and a desired RNA (e.g., a tRNA-based molecule).

20 The following exemplifies this invention with a type 2 pol III promoter and a tRNA gene. Specifically to illustrate the broad invention, the RNA molecule in the following example has an A box and a B box of the type 2 pol III promoter system and has a 5' terminus or region able to base-pair with at least 8 bases of a complementary 3' end or region of the same RNA  
25 molecule. This is meant to be a specific example. Those in the art will recognize that this is but one example, and other embodiments can be readily generated using other pol III promoter systems and techniques generally known in the art.

30 By "terminus" is meant the terminal bases of an RNA molecule, ending in a 3' hydroxyl or 5' phosphate or 5' cap moiety. By "region" is meant a stretch of bases 5' or 3' from the terminus that are involved in base-paired interactions. It need not be adjacent to the end of the RNA. Applicant has determined that base pairing of at least one end of the RNA molecule with a region not more than about 50 bases, and preferably only 20 bases, from

the other end of the molecule provides a useful molecule able to be expressed at high levels.

By "3' region" is meant a stretch of bases 3' from the terminus that are involved in intramolecular base-paired interaction with complementary nucleotides in the 5' terminus of the same molecule. The 3' region can be designed to include the 3' terminus. The 3' region therefore is  $\geq 0$  nucleotides from the 3' terminus. For example, in the S35 construct described in the present invention (Fig. 40) the 3' region is one nucleotide from the 3' terminus. In another example, the 3' region is  $\sim 43$  nt from 3' terminus. These examples are not meant to be limiting. Those in the art will recognize that other embodiments can be readily generated using techniques generally known in the art. Generally, it is preferred to have the 3' region within 100 bases of the 3' terminus.

By "tRNA molecule" is meant a type 2 pol III driven RNA molecule that is generally derived from any recognized tRNA gene. Those in the art will recognize that DNA encoding such molecules is readily available and can be modified as desired to alter one or more bases within the DNA encoding the RNA molecule and/or the promoter system. Generally, but not always, such molecules include an A box and a B box that consist of sequences which are well known in the art (and examples of which can be found throughout the literature). These A and B boxes have a certain consensus sequence which is essential for a optimal pol III transcription.

By "chimeric tRNA molecule" is meant a RNA molecule that includes a pol III promoter (type 2) region. A chimeric tRNA molecule, for example, might contain an intramolecular base-paired structure between the 3' region and complementary 5' terminus of the molecule, and includes a foreign RNA sequence at any location within the molecule which does not affect the activity of the type 2 pol III promoter boxes. Thus, such a foreign RNA may be provided at the 3' end of the B box, or may be provided in between the A and the B box, with the B box moved to an appropriate location either within the foreign RNA or another location such that it is effective to provide pol III transcription. In one example, the RNA molecule may include a hammerhead ribozyme with the B box of a type 2 pol III promoter provided in stem II of the ribozyme. In a second example, the B box may be provided in stem IV region of a hairpin ribozyme. A specific example of such RNA molecules is provided below. Those in the art will

recognize that this is but one example, and other embodiments can be readily generated using techniques generally known in the art.

By "desired RNA" molecule is meant any foreign RNA molecule which is useful from a therapeutic, diagnostic, or other viewpoint. Such molecules include antisense RNA molecules, decoy RNA molecules, enzymatic RNA, therapeutic editing RNA and agonist and antagonist RNA.

By "antisense RNA" is meant a non-enzymatic RNA molecule that binds to another RNA (target RNA) by means of RNA-RNA interactions and alters the activity of the target RNA (Eguchi et al., 1991 *Annu. Rev. Biochem.* 60, 631-652). By "enzymatic RNA" is meant an RNA molecule with enzymatic activity (Cech, 1988 *J. American. Med. Assoc.* 260, 3030-3035). Enzymatic nucleic acids (ribozymes) act by first binding to a target RNA. Such binding occurs through the target binding portion of a enzymatic nucleic acid which is held in close proximity to an enzymatic portion of the molecule that acts to cleave the target RNA. Thus, the enzymatic nucleic acid first recognizes and then binds a target RNA through base-pairing, and once bound to the correct site, acts enzymatically to cut the target RNA.

By "decoy RNA" is meant an RNA molecule that mimics the natural binding domain for a ligand. The decoy RNA therefore competes with natural binding target for the binding of a specific ligand. For example, it has been shown that over-expression of HIV trans-activation response (TAR) RNA can act as a "decoy" and efficiently binds HIV *tat* protein, thereby preventing it from binding to TAR sequences encoded in the HIV RNA (Sullenger et al., 1990 *Cell* 63, 601-608). This is meant to be a specific example. Those in the art will recognize that this is but one example, and other embodiments can be readily generated using techniques generally known in the art.

By "therapeutic editing RNA" is meant an antisense RNA that can bind to its cellular target (RNA or DNA) and mediate the modification of a specific base.

By "agonist RNA" is meant an RNA molecule that can bind to protein receptors with high affinity and cause the stimulation of specific cellular pathways.

By "antagonist RNA" is meant an RNA molecule that can bind to cellular proteins and prevent it from performing its normal biological function (for example, see Tsai et al., 1992 *Proc. Natl. Acad. Sci. USA* 89, 8864-8868).

5 In other aspects, the invention includes vectors encoding RNA molecules as described above, cells including such vectors, methods for producing the desired RNA, and use of the vectors and cells to produce this RNA.

10 Thus, the invention features a transcribed non-naturally occurring RNA molecule which includes a desired therapeutic RNA portion and an intramolecular stem formed by base-pairing interactions between a 3' region and complementary nucleotides at the 5' terminus in the RNA. The stem preferably includes at least 8 base pairs, but may have more, for example, 15 or 16 base pairs.

15 In preferred embodiments, the 5' terminus of the chimeric tRNA includes a portion of the precursor molecule of the primary tRNA molecule, of which  $\geq 8$  nucleotides are involved in base-pairing interaction with the 3' region; the chimeric tRNA contains A and B boxes; natural sequences 3' of the B box are deleted, which prevents endogenous RNA processing; the  
20 desired RNA molecule is at the 3' end of the B box; the desired RNA molecule is between the A and the B box; the desired RNA molecule includes the B box; the desired RNA molecule is selected from the group consisting of antisense RNA, decoy RNA, therapeutic editing RNA, enzymatic RNA, agonist RNA and antagonist RNA; the molecule has an  
25 intramolecular stem resulting from a base-paired interaction between the 5' terminus of the RNA and a complementary 3' region within the same RNA, and includes at least 8 bases; and the 5' terminus is able to base pair with at least 15 bases of the 3' region.

30 In most preferred embodiments, the molecule is transcribed by a RNA polymerase III based promoter system, e.g., a type 2 pol III promoter system; the molecule is a chimeric tRNA, and may have the A and B boxes of a type 2 pol III promoter separated by between 0 and 300 bases; DNA vector encoding the RNA molecule of claim 51.

In other related aspects, the invention features an RNA or DNA vector encoding the above RNA molecule, with the portions of the vector encoding the RNA functioning as a RNA pol III promoter; or a cell containing the vector ; or a method to provide a desired RNA molecule in a cell, by  
5 introducing the molecule into a cell with an RNA molecule as described above. The cells can be derived from animals, plants or human beings.

In order for RNA-based gene therapy approaches to be effective, sufficient amounts of the therapeutic RNA must accumulate in the appropriate intracellular compartment of the treated cells. Accumulation is  
10 a function of both promoter strength of the antiviral gene, and the intracellular stability of the antiviral RNA. Both RNA polymerase II (pol II) and RNA polymerase III (pol III) based expression systems have been used to produce therapeutic RNAs in cells (Sarver & Rossi, 1993 *AIDS Res. & Human Retroviruses* 9, 483-487; Yu et al., 1993 *P.N.A.S.(USA)* 90, 6340-  
15 6344). However, pol III based expression cassettes are theoretically more attractive for use in expressing antiviral RNAs for the following reasons. Pol II produces messenger RNAs located exclusively in the cytoplasm, whereas pol III produces functional RNAs found in both the nucleus and the cytoplasm. Pol II promoters tend to be more tissue restricted, whereas pol  
20 III genes encode tRNAs and other functional RNAs necessary for basic "housekeeping" functions in all cell types. Therefore, pol III promoters are likely to be expressed in all tissue types. Finally, pol III transcripts from a given gene accumulate to much greater levels in cells relative to pol II genes.

25 Intracellular accumulation of therapeutic RNAs is also dependent on the method of gene transfer used. For example, the retroviral vectors presently used to accomplish stable gene transfer, integrate randomly into the genome of target cells. This random integration leads to varied expression of the transferred gene in individual cells comprising the bulk  
30 treated cell population. Therefore, for maximum effectiveness, the transferred gene must have the capacity to express therapeutic amounts of the antiviral RNA in the entire treated cell population, regardless of the integration site.

### Pol III System

The following is just one non-limiting example of the invention. A pol III based genetic element derived from a human tRNA<sub>i</sub><sup>met</sup> gene and termed  $\Delta 3-5$  (Fig. 33; Adeniyi-Jones et al., 1984 *supra*), has been adapted to express antiviral RNAs (Sullenger et al., 1990 *Mol. Cell. Biol.* 10, 6512-6523). This element was inserted into the DC retroviral vector (Sullenger et al., 1990 *Mol. Cell. Biol.* 10, 6512-6523) to accomplish stable gene transfer, and used to express antisense RNAs against moloney murine leukemia virus and anti-HIV decoy RNAs (Sullenger et al., 1990 *Mol. Cell. Biol.* 10, 6512-6523; Sullenger et al., 1990 *Cell* 63, 601-608; Sullenger et al., 1991 *J. Virol.* 65, 6811-6816; Lee et al., 1992 *The New Biologist* 4, 66-74). Clonal lines are expanded from individual cells present in the bulk population, and therefore express similar amounts of the therapeutic RNA in all cells. Development of a vector system that generates therapeutic levels of therapeutic RNA in all treated cells would represent a significant advancement in RNA based gene therapy modalities.

Applicant examined hammerhead (HHI) ribozyme (RNA with enzymatic activity) expression in human T cell lines using the  $\Delta 3-5$  vector system (These constructs are termed " $\Delta 3-5$ /HHI"; Fig. 34). On average, ribozymes were found to accumulate to less than 100 copies per cell in the bulk T cell populations. In an attempt to improve expression levels of the  $\Delta 3-5$  chimera, the applicant made a series of modified  $\Delta 3-5$  gene units containing enhanced promoter elements to increase transcription rates, and inserted structural elements to improve the intracellular stability of the ribozyme transcripts (Fig. 34). One of these modified gene units, termed S35, gave rise to more than a 100-fold increase in ribozyme accumulation in bulk T cell populations relative to the original  $\Delta 3-5$ /HHI vector system. Ribozyme accumulation in individual clonal lines from the pooled T cell populations ranged from 10 to greater than 100 fold more than those achieved with the original  $\Delta 3-5$ /HHI version of this vector.

The S35 gene unit may be used to express other therapeutic RNAs including, but not limited to, ribozymes, antisense, decoy, therapeutic editing, agonist and antagonist RNAs. Application of the S35 gene unit would not be limited to antiviral therapies, but also to other diseases, such as cancer, in which therapeutic RNAs may be effective. The S35 gene unit may be used in the context of other vector systems besides retroviral

vectors, including but not limited to, other stable gene transfer systems such as adeno-associated virus (AAV; Carter, 1992 *Curr. Opin. Genet. Dev.* 3, 74), as well as transient vector systems such as plasmid delivery and adenoviral vectors (Berkner, 1988 *BioTechniques* 6, 616-629).

- 5 As described below, the S35 vector encodes a truncated version of a tRNA wherein the 3' region of the RNA is base-paired to complementary nucleotides at the 5' terminus, which includes the 5' precursor portion that is normally processed off during tRNA maturation. Without being bound by any theory, Applicant believes this feature is important in the level of  
10 expression observed. Thus, those in the art can now design equivalent RNA molecules with such high expression levels. Below are provided examples of the methodology by which such vectors and tRNA molecules can be made.

#### $\Delta$ 3-5 Vectors

- 15 The use of a truncated human tRNA<sup>met</sup> gene, termed  $\Delta$ 3-5 (Fig. 33; Adeniyi-Jones et al., 1984 *supra*), to drive expression of antisense RNAs, and subsequently decoy RNAs (Sullenger et al., 1990 *supra*) has recently been reported. Because tRNA genes utilize internal pol III promoters, the antisense and decoy RNA sequences were expressed as chimeras  
20 containing tRNA<sup>met</sup> sequences. The truncated tRNA genes were placed into the U3 region of the 3' moloney murine leukemia virus vector LTR (Sullenger et al., 1990 *supra*).

#### Base-Paired Structures

- Since the  $\Delta$ 3-5 vector combination has been successfully used to  
25 express inhibitory levels of both antisense and decoy RNAs, applicant cloned ribozyme-encoding sequences (termed as " $\Delta$ 3-5/HHI") into this vector to explore its utility for expressing therapeutic ribozymes. However, low ribozyme accumulation in human T cell lines stably transduced with this vector was observed (Fig. 35). To try and improve accumulation of the  
30 ribozyme, applicant incorporated various RNA structural elements (Fig. 34) into one of the ribozyme chimeras ( $\Delta$ 3-5/HHI).

Two strategies were used to try and protect the termini of the chimeric transcripts from exonucleolytic degradation. One strategy involved the incorporation of stem-loop structures into the termini of the transcript. Two

such constructs were cloned, S3 which contains a stem-loop structure at the 3' end, and S5 which contains stem-loop structures at both ends of the transcript (Figure 34). The second strategy involved modification of the 3' terminal sequences such that the 5' terminus and the 3' end sequences can form a stable base-paired stem. Two such constructs were made: S35 in which the 3' end was altered to hybridize to the 5' leader and acceptor stem of the tRNA<sup>met</sup> domain, and S35Plus which was identical to S35 but included more extensive structure formation within the non-ribozyme portion of the  $\Delta 3-5$  chimeras (Figure 34). These stem-loop structures are also intended to sequester non-ribozyme sequences in structures that will prevent them from interfering with the catalytic activity of the ribozyme. These constructs were cloned, producer cell lines were generated, and stably-transduced human MT2 (Harada et al., 1985 *supra*) and CEM (Nara & Fischinger, 1988 *supra*) cell lines were established (*Curr. Protocols Mol. Biol.* 1992, ed. Ausubel et al., Wiley & Sons, NY). The RNA sequences and structure of S35 and S35 Plus are provided in Figures 40-47.

Referring to Figure 48, there is provided a general structure for a chimeric RNA molecule of this invention. Each N independently represents none or a number of bases which may or may not be base paired. The A and B boxes are optional and can be any known A or B box, or a consensus sequence as exemplified in the figure. The desired nucleic acid to be expressed can be any location in the molecule, but preferably is on those places shown adjacent to or between the A and B boxes (designated by arrows). Figure 49 shows one example of such a structure in which a desired RNA is provided 3' of the intramolecular stem. A specific example of such a construct is provided in Figures 50 and 51.

#### Example 26: Cloning of $\Delta 3-5$ -Ribozyme Chimera

Oligonucleotides encoding the S35 insert that overlap by at least 15 nucleotides were designed (5' GATCCACTCTGCTGTTCTGTTTTGA 3' and 5' CGCGTCAAAAACAGAACAGCAGAGTG 3'). The oligonucleotides (10  $\mu$ M each) were denatured by boiling for 5 min in a buffer containing 40 mM Tris.HCl, pH8.0. The oligonucleotides were allowed to anneal by snap cooling on ice for 10-15 min.

The annealed oligonucleotide mixture was converted into a double-stranded molecule using Sequenase<sup>®</sup> enzyme (US Biochemicals) in a



buffer containing 40 mM Tris.HCl, pH7.5, 20 mM MgCl<sub>2</sub>, 50 mM NaCl, 0.5 mM each of the four deoxyribonucleotide triphosphates, 10 mM DTT. The reaction was allowed to proceed at 37°C for 30 min. The reaction was stopped by heating to 70°C for 15 min.

- 5        The double stranded DNA was digested with appropriate restriction endonucleases (*Bam*HI and *Mlu*I) to generate ends that were suitable for cloning into the Δ3-5 vector.

          The double-stranded insert DNA was ligated to the Δ3-5 vector DNA by incubating at room temperature (about 20°C) for 60 min in a buffer  
10        containing 66 mM Tris.HCl, pH 7.6, 6.6 mM MgCl<sub>2</sub>, 10 mM DTT, 0.066 μM ATP and 0.1U/μl T4 DNA Ligase (US Biochemicals).

          Competent *E. coli* bacterial strain was transformed with the recombinant vector DNA by mixing the cells and DNA on ice for 60 min. The mixture was heat-shocked by heating to 37°C for 1 min. The reaction  
15        mixture was diluted with LB media and the cells were allowed to recover for 60 min at 37°C. The cells were plated on LB agar plates and incubated at 37°C for ~ 18 h.

          Plasmid DNA was isolated from an overnight culture of recombinant clones using standard protocols (Ausubel et al., *Curr. Protocols Mol.*  
20        *Biology* 1990, Wiley & Sons, NY).

          The identity of the clones were determined by sequencing the plasmid DNA using the Sequenase<sup>®</sup> DNA sequencing kit (US Biochemicals).

          The resulting recombinant Δ3-5 vector contains the S35 sequence. The HHI encoding DNA was cloned into this Δ3-5-S35 containing vector  
25        using *Sac*II and *Bam*HI restriction sites.

#### Example 27: Northern analysis

          RNA from the transduced MT2 cells were extracted and the presence of Δ3-5/ribozyme chimeric transcripts were assayed by Northern analysis (*Curr. Protocols Mol. Biol.* 1992, ed. Ausubel et al., Wiley & Sons, NY).  
30        Northern analysis of RNA extracted from MT2 transductants showed that Δ3-5/ribozyme chimeras of appropriate sizes were expressed (Fig. 35,36). In addition, these results demonstrated the relative differences in accumulation among the different constructs (Figure 35,36). The pattern of

expression seen from the  $\Delta 3$ -5/HHI ribozyme chimera was similar to 12 other ribozymes cloned into the  $\Delta 3$ -5 vector (not shown). In MT-2 cell line,  $\Delta 3$ -5/HHI ribozyme chimeras accumulated, on average, to less than 100 copies per cell.

- 5        Addition of a stem-loop onto the 3' end of  $\Delta 3$ -5/HHI did not lead to increased  $\Delta 3$ -5 levels (S3 in [Fig. 35,36](#)). The S5 construct containing both 5' and 3' stem-loop structures also did not lead to increased ribozyme levels ([Fig. 35,36](#)).

- 10       Interestingly, the S35 construct expression in MT2 cells was about 100-fold more abundant relative to the original  $\Delta 3$ -5/HHI vector transcripts ([Fig. 35,36](#)). This may be due to increased stability of the S35 transcript.

#### Example 28: Cleavage activity

- 15       To assay whether ribozymes transcribed in the transduced cells contained cleavage activity, total RNA extracted from the transduced MT2 T cells were incubated with a labeled substrate containing the HHI cleavage site ([Figure 37](#)). Ribozyme activity in all but the S35 constructs, was too low to detect. However, ribozyme activity was detectable in S35-transduced T cell RNA. Comparison of the activity observed in the S35-transduced MT2 RNA with that seen with MT2 RNA in which varying
- 20       amounts of in vitro transcribed S5 ribozyme chimeras, indicated that between 1-3 nM of S35 ribozyme was present in S35-transduced MT2 RNA. This level of activity corresponds to an intracellular concentration of 5,000-15,000 ribozyme molecules per cell.

#### Example 29: Clonal variation

- 25       Variation in the ribozyme expression levels among cells making up the bulk population was determined by generating several clonal cell lines from the bulk S35 transduced CEM line (*Curr. Protocols Mol. Biol.* 1992, ed. Ausubel et al., Wiley & Sons, NY) and the ribozyme expression and activity levels in the individual clones were measured ([Figure 38 and 39](#)).
- 30       All the individual clones were found to express active ribozyme. The ribozyme activity detected from each clone correlated well with the relative amounts of ribozyme observed by Northern analysis. Steady state ribozyme levels among the clones ranged from approximately 1,000 molecules per cell in clone G to 11,000 molecules per cell in clone H ([Fig.](#)

38). The mean accumulation among the clones, calculated by averaging the ribozyme levels of the clones, exactly equaled the level measured in the parent bulk population. This suggests that the individual clones are representative of the variation present in the bulk population.

- 5        The fact that all 14 clones were found to express ribozyme indicate that the percentage of cells in the bulk population expressing ribozyme is also very high. In addition, the lowest level of expression in the clones was still more than 10-fold that seen in bulk cells transduced with the original  $\Delta 3-5$  vector. Therefore, the S35 gene unit should be much more effective  
10        in a gene therapy setting in which bulk cells are removed, transduced and then reintroduced back into a patient.

Example 30: Stability

- Finally, the bulk S35-transduced line, resistant to G418, was propagated for a period of 3 months (in the absence of G418) to determine  
15        if ribozyme expression was stable over extended periods of time. This situation mimicks that found in the clinic in which bulk cells are transduced and then reintroduced into the patient and allowed to propagate. There was a modest 30% reduction of ribozyme expression after 3 months. This difference probably arose from cells with varying amount of ribozyme  
20        expression and exhibiting different growth rates in the culture becoming slightly more prevalent in the culture. However, ribozyme expression is apparently stable for at least this period of time.

Example 31: Design and construction of TRZ-tRNA Chimera

- A transcription unit, termed TRZ, is designed that contains the S35  
25        motif (Figure 52). A desired RNA (e.g. ribozyme) can be inserted into the indicated region of TRZ tRNA chimera. This construct might provide additional stability to the desired RNA. TRZ-A and TRZ-B are non-limiting examples of the TRZ-tRNA chimera.

- Referring to Fig. 53-54, a hammerhead ribozyme targeted to site I  
30        (HHITRZ-A; Fig. 53) and a hairpin ribozyme (HPITRZ-A; Fig. 54), also targeted to site I, is cloned individually into the indicated region of TRZ tRNA chimera. The resulting ribozyme transcripts retain full RNA cleavage activity (see for example Fig. 55). Applicant has shown that efficient

expression of these TRZ tRNA chimera can be achieved in mammalian cells.

Besides ribozymes, desired RNAs like antisense, therapeutic editing RNAs, decoys, can be readily inserted into the indicated region of TRZ-tRNA chimera to achieve therapeutic levels of RNA expression in mammalian cells.

Sequences listed in Figures 40-47 and 50 - 54 are meant to be non-limiting examples. Those skilled in the art will recognize that variants (mutations, insertions and deletions) of the above examples can be readily generated using techniques known in the art, are within the scope of the present invention.

Example 32: Ribozyme expression in T cell lines

Ribozyme expression in T cell lines stably-transduced with either a retroviral-based or an Adeno-associated virus (AAV)-based ribozyme expression vector (Figure 56). The human T cell lines MT2 and CEM were transduced with either retroviral or AAV vectors encoding a neomycin selectable marker and a ribozyme (S35/HHI) expressed from pol III met; tRNA-driven promoter. Cells stably-transduced with the vectors were selectively expanded medium containing the neomycin antibiotic derivative, G418 (0.7 mg/ml). Ribozyme expression in the stable cell lines was then analyzed by Northern analysis. The probe used to detect ribozyme transcripts also cross-hybridized with human met; tRNA sequences. Referring to Figure 56, S35/HHI RNA accumulates to significant levels in MT2 and CEM cells when transduced with either the retrovirus or the AAV vector.

These are meant to be non-limiting examples, those skilled in the art will recognize that other vectors such as adenovirus vector (Figure 57), plasmid DNA vector, alpha virus vectors and the other derivatives thereof, can be readily generated to deliver the desired RNA, using techniques known in the art and are within the scope of this invention. Additionally, the transcription units can be expressed individually or in multiples using pol II and/or pol III promoters.

References cited herein, as well as Draper WO 93/23569, 94/02495, 94/06331, Sullenger WO 93/12657, Thompson WO 93/04573, and Sullivan

WO 94/04609, and 93/11253 describe methods for use of vectors described herein, and are incorporated by reference herein. In particular these vectors are useful for administration of antisense and decoy RNA molecules.

5 Example 33: Ligated Ribozymes are catalytically active

The ability of ribozymes generated by ligation methods, described in Draper et al., PCT WO 93/23569, to cleave target RNA was tested on either matched substrate RNA (Fig. 58) or long (622 nt) RNA (Fig. 59, 60 and 61).

10 Matched substrate RNAs were chemically synthesized using solid-phase RNA synthesis chemistry (Scaringe et al., 1990 Nucleic Acids Res. 18, 5433-5441). Substrate RNA was 5' end-labeled using [ $\gamma$ - $^{32}$ P] ATP and polynucleotide kinase (Curr. Protocols Mol. Biol. 1992, ed. Ausubel et al., Wiley & Sons, NY). Ribozyme reactions were carried out under ribozyme excess conditions ( $k_{cat}/K_M$ ; Herschlag and Cech, 1990 Biochemistry 29, 10159-10171). Briefly, ribozyme and substrate RNA were denatured and  
15 renatured separately by heating to 90°C and snap cooling on ice for 10 min in a buffer containing 50 mM Tris, HCl pH 7.5 and 10 mM MgCl<sub>2</sub>. Cleavage reaction was initiated by mixing the ribozyme with the substrate at 37°C. Aliquots of 5  $\mu$ l were taken at regular intervals of time and the  
20 reaction was stopped by mixing with equal volume of formamide gel loading buffer (Curr. Protocols Mol. Biol. 1992, ed. Ausubel et al., Wiley & Sons, NY). The samples were resolved on 20 % polyacrylamide-urea gel. Referring to Fig. 58,  $-\Delta G$  refers to the free energy of binding calculated for base-paired interactions between the ribozyme and the substrate RNA  
25 (Turner and Sugimoto, 1988 Supra). RPI A is a HH ribozyme with 6/6 binding arms. This ribozyme was synthesized chemically either as a one piece ribozyme or was synthesized in two fragments followed by ligation to generate a one piece ribozyme. The  $k_{cat}/K_M$  values for the two ribozymes were comparable.

30 A template containing T7 RNA polymerase promoter upstream of 622 nt long target sequence, was PCR amplified from a DNA clone. The target RNA (containing HH ribozyme cleavage sites B, C and D) was transcribed from this PCR amplified template using T7 RNA polymerase. The transcript was internally labeled during transcription by including [ $\alpha$ - $^{32}$ P] CTP as one  
35 of the four ribonucleotide triphosphates. The transcription mixture was

treated with DNase-1, following transcription at 37°C for 2 hours, to digest away the DNA template used in the transcription. RNA was precipitated with Isopropanol and the pellet was washed two times with 70% ethanol to get rid of salt and nucleotides used in the transcription reaction. RNA is resuspended in DEPC-treated water and stored at 4°C. Ribozyme cleavage reactions were carried out under ribozyme excess ( $k_{cat}/K_M$ ) conditions [Herschlag and Cech 1990 *supra*]. Briefly, 1000 nM ribozyme and 10 nM internally labeled target RNA were denatured separately by heating to 90°C for 2 min in the presence of 50 mM Tris.HCl, pH 7.5 and 10 mM MgCl<sub>2</sub>. The RNAs were renatured by cooling to 37°C for 10-20 min. Cleavage reaction was initiated by mixing the ribozyme and target RNA at 37°C. Aliquots of 5 µl were taken at regular intervals of time and the reaction was quenched by adding equal volume of stop buffer. The samples were resolved on a sequencing gel.

15 Example 34: Hammerhead ribozymes with  $\geq 2$  base-paired stem II are catalytically active

To decrease the cost of chemical synthesis of RNA, applicant was interested in determining whether the length of stem II region of a typical hammerhead ribozyme ( $\geq 4$  bp stem II) can be shortened without decreasing the catalytic efficiency of the HH ribozyme. The length of stem II was systematically shortened by one base-pair at a time. HH ribozymes with three and two base-paired stem II were chemically synthesized using solid-phase RNA phosphoramidite chemistry (Scaringe *et al.*, 1990 *supra*).

Matched and long substrate RNAs were synthesized and ribozyme assays were carried out as described in example 33. Referring to figures 62, 63 and 64, data shows that shortening stem II of a hammerhead ribozyme does not significantly alter the catalytic efficiency. It is applicant's opinion that hammerhead ribozymes with  $\geq 2$  base-paired stem II region are catalytically active.

30 Example 35: Synthesis of catalytically active hairpin ribozymes

RNA molecules were chemically synthesized having the nucleotide base sequence shown in Fig. 65 for both the 5' and 3' fragments. The 3' fragments are phosphorylated and ligated to the 5' fragment essentially as described in example 37. As is evident from the Figure 65, the 3' and 5' fragments can hybridize together at helix 4 and are covalently linked via

GAAA sequence. When this structure hybridizes to a substrate, a ribozyme-substrate complex structure is formed. While helix 4 is shown as 3 base pairs it may be formed with only 1 or 2 base pairs.

40 nM mixtures of ligated ribozymes were incubated with 1-5 nM 5' end-labeled matched substrates (chemically synthesized by solid-phase synthesis using RNA phosphoramidite chemistry) for different times in 50 mM Tris/HCl pH 7.5, 10 mM MgCl<sub>2</sub> and shown to cleave the substrate efficiently (Fig.66).

The target and the ribozyme sequences shown in Fig. 62 and 65 are meant to be non-limiting examples. Those in the art will recognize that other embodiments can be readily generated using other sequences and techniques generally known in the art.

#### V. Constructs of Hairpin Ribozymes

There follows an improved trans-cleaving hairpin ribozyme in which a new helix (*i.e.*, a sequence able to form a double-stranded region with another single-stranded nucleic acid) is provided in the ribozyme to base-pair with a 5' region of a separate substrate nucleic acid. This helix is provided at the 3' end of the ribozyme after helix 3 as shown in Figure 3. In addition, at least two extra bases may be provided in helix 2 and a portion of the substrate corresponding to helix 2 may be either directly linked to the 5' portion able to hydrogen bond to the 3' end of the hairpin or may have a linker of at least one base. By trans-cleaving is meant that the ribozyme is able to act in *trans* to cleave another RNA molecule which is not covalently linked to the ribozyme itself. Thus, the ribozyme is not able to act on itself in an intramolecular cleavage reaction.

By "base-pair" is meant a nucleic acid that can form hydrogen bond(s) with other RNA sequence by either traditional Watson-Crick or other non-traditional types (for example Hoogsteen type) of interactions.

The increase in length of helix 2 of a hairpin ribozyme (with or without helix 5) has several advantages. These include improved stability of the ribozyme-target complex *in vivo*. In addition, an increase in the recognition sequence of the hairpin ribozyme improves the specificity of the ribozyme. This also makes possible the targeting of potential hairpin

ribozyme sites that would otherwise be inaccessible due to neighboring secondary structure.

- The increase in length of helix 2 of a hairpin ribozyme (with or without helix 5) enhances *trans*-ligation reaction catalyzed by the ribozyme. *Trans*-ligation reactions catalyzed by the regular hairpin ribozyme (4 bp helix 2) is very inefficient (Komatsu *et al.*, 1993 *Nucleic Acids Res.* 21, 185). This is attributed to weak base-pairing interactions between substrate RNAs and the ribozyme. By increasing the length of helix 2 (with or without helix 5) the rate of ligation (*in vitro* and *in vivo*) can be enhanced several fold.
- Results of experiments suggest that the length of H2 can be 6 bp without significantly reducing the activity of the hairpin ribozyme. The H2 arm length variation does not appear to be sequence dependent. HP ribozymes with 6 bp H2 have been designed against five different target RNAs and all five ribozymes efficiently cleaved their cognate target RNA. Additionally, two of these ribozymes were able to successfully inhibit gene expression (e.g., TNF- $\alpha$ ) in mammalian cells. Results of these experiments are shown below.

- HP ribozymes with 7 and 8 bp H2 are also capable of cleaving target RNA in a sequence-specific manner, however, the rate of the cleavage reaction is lower than those catalyzed by HP ribozymes with 6 bp H2.

Example 36: 4 and 6 base pair H2

Referring to Figures 67-72, HP ribozymes were synthesized as described above and tested for activity. Surprisingly, those with 6 base pairs in H2 were still as active as those with 4 base pairs.

VI. Chemical Modification

Oligonucleotides with 5'-C-alkyl Group

- The introduction of an alkyl group at the 5'-position of a nucleoside or nucleotide sugar introduces an additional center of chirality into the sugar moiety. Referring to Fig. 75, the general structures of 5'-C-alkylnucleotides belonging to the D-allose, 2, and L-talose, 3, sugar families are shown. The family names are derived from the known sugars D-allose and L-talose ( $R_1 = CH_3$  in 2 and 3 in Figure 75). Useful specific D-allose and L-talose



nucleotide derivatives are shown in Figure 76, 29-32 and Figure 77, 58-61 respectively.

This invention relates to the use of 5'-C-alkylnucleotides in oligonucleotides, which are particularly useful for enzymatic cleavage of RNA or single-stranded DNA, and also as antisense oligonucleotides. As the term is used in this application, 5'-C-alkylnucleotide-containing enzymatic nucleic acids are catalytic nucleic molecules that contain 5'-C-alkylnucleotide components replacing, but not limited to, double stranded stems, single stranded "catalytic core" sequences, single-stranded loops or single-stranded recognition sequences. These molecules are able to cleave (preferably, repeatedly cleave) separate RNA or DNA molecules in a nucleotide base sequence specific manner. Such catalytic nucleic acids can also act to cleave intramolecularly if that is desired. Such enzymatic molecules can be targeted to virtually any RNA transcript.

Also within the invention are 5'-C-alkylnucleotides which may be present in enzymatic nucleic acid or even in antisense oligonucleotides. Such nucleotides are useful since they enhance the stability of the antisense or enzymatic molecule, and can be used in locations which do not affect the desired activity of the molecule. That is, while the presence of the 5'-C-alkyl group may reduce binding affinity of the oligonucleotide containing this modification, if that moiety is not in an essential base pair forming region then the enhanced stability that it provides to the molecule is advantageous. In addition, while the reduced binding may reduce enzymatic activity, the enhanced stability may make the loss of activity of less consequence. Thus, for example, if a 5'-C-alkyl-containing molecule has 10% the activity of the unmodified molecule, but has 10-fold higher stability *in vivo* then it has utility in the present invention. The same analysis is true for antisense oligonucleotides containing such modifications. The invention also relates to novel intermediates useful in the synthesis of such nucleotides and oligonucleotides (examples of which are shown in the Figures), and to methods for their synthesis.

Thus, in one aspect, the invention features 5'-C-alkylnucleosides, that is a nucleotide base having at the 5'-position on the sugar molecule an alkyl moiety. In a related aspect, the invention also features 5'-C-alkylnucleotides, and in preferred embodiments features those where the nucleotide is not uridine or thymidine. That is, the invention preferably

includes all those nucleotides useful for making enzymatic nucleic acids or antisense molecules that are not described by the art discussed above. In preferred embodiments, the sugar of the nucleoside or nucleotide is in an optically pure form, as the talose or allose sugar.

5        Examples of various alkyl groups useful in this invention are shown in Figure 75, where each  $R_1$  group is any alkyl. These examples are not limiting in the invention. Specifically, an "alkyl" group refers to a saturated aliphatic hydrocarbon, including straight-chain, branched-chain, and cyclic alkyl groups. Preferably, the alkyl group has 1 to 12 carbons. More  
10        preferably it is a lower alkyl of from 1 to 7 carbons, more preferably 1 to 4 carbons. The alkyl group may be substituted or unsubstituted. When substituted the substituted group(s) is preferably, hydroxyl, cyano, alkoxy,  $=O$ ,  $=S$ ,  $NO_2$  or  $N(CH_3)_2$ , amino, or  $SH$ . The term also includes alkenyl groups which are unsaturated hydrocarbon groups containing at least one  
15        carbon-carbon double bond, including straight-chain, branched-chain, and cyclic groups. Preferably, the alkenyl group has 1 to 12 carbons. More preferably it is a lower alkenyl of from 1 to 7 carbons, more preferably 1 to 4 carbons. The alkenyl group may be substituted or unsubstituted. When substituted the substituted group(s) is preferably, hydroxyl, cyano, alkoxy,  
20         $=O$ ,  $=S$ ,  $NO_2$ , halogen,  $N(CH_3)_2$ , amino, or  $SH$ . The term "alkyl" also includes alkynyl groups which have an unsaturated hydrocarbon group containing at least one carbon-carbon triple bond, including straight-chain, branched-chain, and cyclic groups. Preferably, the alkynyl group has 1 to 12 carbons. More preferably it is a lower alkynyl of from 1 to 7 carbons,  
25        more preferably 1 to 4 carbons. The alkynyl group may be substituted or unsubstituted. When substituted the substituted group(s) is preferably, hydroxyl, cyano, alkoxy,  $=O$ ,  $=S$ ,  $NO_2$  or  $N(CH_3)_2$ , amino or  $SH$ .

Such alkyl groups may also include aryl, alkylaryl, carbocyclic aryl, heterocyclic aryl, amide and ester groups. An "aryl" group refers to an  
30        aromatic group which has at least one ring having a conjugated  $\pi$  electron system and includes carbocyclic aryl, heterocyclic aryl and biaryl groups, all of which may be optionally substituted. The preferred substituent(s) of aryl groups are halogen, trihalomethyl, hydroxyl,  $SH$ ,  $OH$ , cyano, alkoxy, alkyl, alkenyl, alkynyl, and amino groups. An "alkylaryl" group refers to an  
35        alkyl group (as described above) covalently joined to an aryl group (as described above). Carbocyclic aryl groups are groups wherein the ring

atoms on the aromatic ring are all carbon atoms. The carbon atoms are optionally substituted. Heterocyclic aryl groups are groups having from 1 to 3 heteroatoms as ring atoms in the aromatic ring and the remainder of the ring atoms are carbon atoms. Suitable heteroatoms include oxygen, sulfur, and nitrogen, and include furanyl, thienyl, pyridyl, pyrrolyl, N-lower alkyl pyrrolo, pyrimidyl, pyrazinyl, imidazolyl and the like, all optionally substituted. An "amide" refers to an -C(O)-NH-R, where R is either alkyl, aryl, alkylaryl or hydrogen. An "ester" refers to an -C(O)-OR', where R is either alkyl, aryl, alkylaryl or hydrogen.

10 In other aspects, also related to those discussed above, the invention features oligonucleotides having one or more 5'-C-alkylnucleotides; e.g. enzymatic nucleic acids having a 5'-C-alkylnucleotide; and a method for producing an enzymatic nucleic acid molecule having enhanced activity to cleave an RNA or single-stranded DNA molecule, by forming the enzymatic  
15 molecule with at least one nucleotide having at its 5'-position an alkyl group. In other related aspects, the invention features 5'-C-alkylnucleotide triphosphates. These triphosphates can be used in standard protocols to form useful oligonucleotides of this invention.

The 5'-C-alkyl derivatives of this invention provide enhanced stability  
20 to the oligonucleotides containing them. While they may also reduce absolute activity in an *in vitro* assay they will provide enhanced overall activity *in vivo*. Below are provided assays to determine which such molecules are useful. Those in the art will recognize that equivalent assays can be readily devised.

25 In another aspect, the invention features a method for conversion of a protected allo sugar to a protected talo sugar. In the method, the protected allo sugar is contacted with triphenyl phosphine, diethylazodicarboxylate, and *p*-nitrobenzoic acid under inversion causing conditions to provide the protected talo sugar. While one example of such conditions is provided  
30 below, those in the art will recognize other such conditions. Applicant has found that such conversion allows for ready synthesis of all types of nucleotide bases as exemplified in the figures.

While this invention is applicable to all oligonucleotides, applicant has found that the modified molecules of this invention are particularly useful for  
35 enzymatic RNA molecules. Thus, below is provided examples of such

molecules. Those in the art will recognize that equivalent procedures can be used to make other molecules without such enzymatic activity. Specifically, Figure 1 shows base numbering of a hammerhead motif in which the numbering of various nucleotides in a hammerhead ribozyme is provided. This is not to be taken as an indication that the Figure is prior art to the pending claims, or that the art discussed is prior art to those claims. Referring to Figure 1, the preferred sequence of a hammerhead ribozyme in a 5'- to 3'-direction of the catalytic core is CUGANGAG[base paired with]CGAAA. In this invention, the use of 5'-C-alkyl substituted nucleotides that maintain or enhance the catalytic activity and or nuclease resistance of the hammerhead ribozyme is described. Substitutions of any nucleotide with any of the modified nucleotides shown in Figure 75 are possible.

The following are non-limiting examples showing the synthesis of nucleic acids using 5'-C-alkyl-substituted phosphoramidites and the syntheses of the amidites.

Example 37: Synthesis of Hammerhead Ribozymes Containing 5'-C-Alkyl-nucleotides & Other Modified Nucleotides

The method of synthesis would follow the procedure for normal RNA synthesis as described in Usman,N.; Ogilvie,K.K.; Jiang,M.-Y.; Cedergren,R.J. *J. Am. Chem. Soc.* 1987, 109, 7845-7854 and in Scaringe,S.A.; Franklyn,C.; Usman,N. *Nucleic Acids Res.* 1990, 18, 5433-5441 and makes use of common nucleic acid protecting and coupling groups, such as dimethoxytrityl at the 5'-end, and phosphoramidites at the 3'-end (compounds 26-29 and 56-59). These 5'-C-alkyl substituted phosphoramidites may be incorporated not only into hammerhead ribozymes, but also into hairpin, hepatitis delta virus, Group 1 or Group 2 intron catalytic nucleic acids, or into antisense oligonucleotides. They are, therefore, of general use in any nucleic acid structure.

Example 38: Methyl-2,3-O-Isopropylidene-6-Deoxy-β-D-allofuranoside (4)

A suspension of L-rhamnose (100 g, 0.55 mol), CuSO<sub>4</sub> (120 g) and conc. H<sub>2</sub>SO<sub>4</sub> (4.0 mL) in 1.0 L of dry acetone was mixed for 24 h at RT, then filtered. Conc. NH<sub>4</sub>OH (5 mL) was added to the filtrate and the newly formed precipitate was filtered. The residue was concentrated *in vacuo*, coevaporated with pyridine (2 x 300 mL), dissolved in pyridine (500 mL) and cooled to 0 °C. A solution of *p*-toluenesulfonylchloride (107 g, 0.56

mmol) in dry DCE (500 mL) was added dropwise over 0.5 h. The reaction mixture was left for 16 h at RT. The reaction was quenched by adding ice-water (0.5 L) and, after mixing for 0.5 h, was extracted with chloroform (0.75 L). The organic layer was washed with H<sub>2</sub>O (2 x 500 mL), 10% H<sub>2</sub>SO<sub>4</sub> (2 x 300 mL), water (2 x 300 mL), sat. NaHCO<sub>3</sub> (2 x 300 mL), brine (2 x 300 mL), dried over MgSO<sub>4</sub> and evaporated to dryness. The residue (115 g) was dissolved in dry MeOH (1 L) and treated with NaOMe (23.2 g, 0.42 mmol) in MeOH. The reaction mixture was left for 16 h at 20 °C, neutralized with dry CO<sub>2</sub> and evaporated to dryness. The residue was suspended in chloroform (750 mL), filtered, concentrated to 100 mL and purified by flash chromatography in CHCl<sub>3</sub> to yield 45 g (37%) of compound 4.

Example 39: Methyl-2,3-O-Isopropylidene-5-O-*t*-Butyldiphenylsilyl-6-Deoxy-β-D-Allofuranoside (5).

To solution of methylfuranoside 4 (12.5 g 62.2 mmol) and AgNO<sub>3</sub> (21.25 g, 125.0 mmol) in dry DMF (300 mL) *t*-butyldiphenylsilyl chloride (22.2 g, 81 mmol) was added dropwise under Ar over 0.5 h. The reaction mixture was stirred for 4 h at RT, diluted with CHCl<sub>3</sub> (200 mL), filtered and evaporated to dryness (below 40 °C using a high vacuum oil pump). The residue was dissolved in CH<sub>2</sub>Cl<sub>2</sub> (300 mL) washed with sat. NaHCO<sub>3</sub> (2 x 50 mL), brine (2 x 50 mL), dried over MgSO<sub>4</sub> and evaporated to dryness. The residue was purified by flash chromatography in CH<sub>2</sub>Cl<sub>2</sub> to yield 20.0 g (75%) of compound 5.

Example 40: Methyl-5-O-*t*-Butyldiphenylsilyl-6-Deoxy-β-D-Allofuranoside (6).

Methylfuranoside 5 (13.5 g, 30.6 mmol) was dissolved in CF<sub>3</sub>COOH:dioxane:H<sub>2</sub>O / 2:1:1 (v/v/v, 200 mL) and stirred at 24 °C for 45 m. The reaction mixture was cooled to -10 °C, neutralized with conc. NH<sub>4</sub>OH (140 mL) and extracted with CH<sub>2</sub>Cl<sub>2</sub> (500 mL). The organic layer was separated, washed with sat. NaHCO<sub>3</sub> (2 x 75 mL), brine (2 x 75 mL), dried over MgSO<sub>4</sub> and evaporated to dryness. The product 6 was purified by flash chromatography using a 0-10% MeOH gradient in CH<sub>2</sub>Cl<sub>2</sub>. Yield 9.0 g (76%).

Example 41: Methyl-2,3-di-O-Benzoyl-5-O-t-Butyldiphenylsilyl-6-Deoxy- $\beta$ -D-Allofuranoside (7).

Methylfuranoside 6 (7.0 g, 17.5 mmol) was coevaporated with pyridine (2 x 100 mL) and dissolved in pyridine (100 mL). Benzoyl chloride (5.4 g, 38.5 mmol) was added and the reaction mixture was left at RT for 16 h. Dry EtOH (50 mL) was added and the reaction mixture was evaporated to dryness after 0.5 h. The residue was dissolved in CH<sub>2</sub>Cl<sub>2</sub> (300 mL), washed with sat. NaHCO<sub>3</sub> (2 x 75 mL), brine (2 x 75 mL) dried over MgSO<sub>4</sub> and evaporated to dryness. The product was purified by flash chromatography in CH<sub>2</sub>Cl<sub>2</sub> to yield 9.5 g (89%) of compound 7.

Example 42: 1-O-Acetyl-2,3-di-O-benzoyl-5-O-t-Butyldiphenylsilyl-6-Deoxy- $\beta$ -D-Allofuranose (8).

Dibenzoate 7 (4.7 g, 7.7 mmol) was dissolved in a mixture of AcOH (10.0 mL), Ac<sub>2</sub>O (20.0 mL) and EtOAc (30 mL) and the reaction mixture was cooled 0 °C. 98% H<sub>2</sub>SO<sub>4</sub> (0.15 mL) was then added. The reaction mixture was kept at 0 °C for 16 h, and then poured into a cold 1:1 mixture of sat. NaHCO<sub>3</sub> and EtOAc (150 mL). After 0.5 h of vigorous stirring the organic phase was separated, washed with brine (2 x 75 mL), dried over MgSO<sub>4</sub>, evaporated to dryness and coevaporated with toluene (2 x 50 mL). The product was purified by flash chromatography using a gradient of 0-5% MeOH in CH<sub>2</sub>Cl<sub>2</sub>. Yield: 4.0 g (82% as a mixture of  $\alpha$  and  $\beta$  isomers).

Example 43: 1-(2',3'-di-O-Benzoyl-5'-O-t-Butyldiphenylsilyl-6'-Deoxy- $\beta$ -D-Allofuranosyl)uracil (9).

Uracil (1.44 g, 11.5 mmol) was suspended in mixture of hexamethyldisilazane (100 mL) and pyridine (50 mL) and boiled under reflux until complete dissolution (3 h) occurred, and then for an additional hour. The reaction mixture was cooled to RT, evaporated to dryness and coevaporated with dry toluene (2 x 50 mL). To the residue was added a solution of acetates 8 (6.36 g, 10.0 mmol) in dry CH<sub>3</sub>CN (100 mL), followed by CF<sub>3</sub>SO<sub>3</sub>SiMe<sub>3</sub> (2.8 g, 12.6 mmol). The reaction mixture was kept at 24 °C for 16 h, concentrated to 1/3 of its original volume, diluted with 100 mL of CH<sub>2</sub>Cl<sub>2</sub> and extracted with sat. NaHCO<sub>3</sub> (2 x 50 mL), brine (2 x 50 mL) dried over MgSO<sub>4</sub>, and evaporated to dryness. The product 9 was purified by flash chromatography using a gradient of 0-5% MeOH in CH<sub>2</sub>Cl<sub>2</sub>. Yield: 5.7 g (80%).

Example 44: *N*<sup>4</sup>-Benzoyl-1-(2',3'-Di-*O*-Benzoyl-5'-*O*-*t*-Butyldiphenylsilyl-6'-Deoxy-β-D-Allofuranosyl)Cytosine (10).

*N*<sup>4</sup>-benzoylcytosine (1.84 g, 8.56 mmol) was suspended in mixture of hexamethyldisilazane (100 mL) and pyridine (50 mL) and boiled under reflux until complete dissolution (3 h) occurred, and then for an additional hour. The reaction mixture was cooled to RT evaporated to dryness and coevaporated with dry toluene (2 x 50 mL). To the residue was added a solution of acetates **8** (3.6 g, 5.6 mmol) in dry CH<sub>3</sub>CN (100 mL), followed by CF<sub>3</sub>SO<sub>3</sub>SiMe<sub>3</sub> (4.76 g, 21.4 mmol). The reaction mixture was boiled under reflux for 5 h, cooled to RT, concentrated to 1/3 of its original volume, diluted with CH<sub>2</sub>Cl<sub>2</sub> (100 mL) and extracted with sat. NaHCO<sub>3</sub> (2 x 50 mL), brine (2 x 50 mL) dried over MgSO<sub>4</sub> and evaporated to dryness. Purification by flash chromatography using a gradient of 0-5% MeOH in CH<sub>2</sub>Cl<sub>2</sub> yielded 1.8 g (55%) of compound **10**.

Example 45: *N*<sup>6</sup>-Benzoyl-9-(2',3'-di-*O*-Benzoyl-5'-*O*-*t*-Butyldiphenylsilyl-6'-Deoxy-β-D-Allofuranosyl)adenine (11).

*N*<sup>6</sup>-benzoyladenine (2.86 g, 11.86 mmol) was suspended in mixture of hexamethyldisilazane (100 mL) and pyridine (50 mL) and boiled under reflux until complete dissolution (7 h) occurred, and then for an additional hour. The reaction mixture was cooled to RT evaporated to dryness and coevaporated with dry toluene (2 x 50 mL). To the residue was added a solution of acetates **8** (3.6 g, 5.6 mmol) in dry CH<sub>3</sub>CN (100 mL) followed by CF<sub>3</sub>SO<sub>3</sub>SiMe<sub>3</sub> (6.59 g, 29.7 mmol). The reaction mixture was boiled under reflux for 8 h, cooled to RT, concentrated to 1/3 of its original volume, diluted with CH<sub>2</sub>Cl<sub>2</sub> (100 mL) and extracted with sat. NaHCO<sub>3</sub> (2 x 50 mL), brine (2 x 50 mL) dried over MgSO<sub>4</sub> and evaporated to dryness. The product **11** was purified by flash chromatography using a gradient of 0-5% MeOH in CH<sub>2</sub>Cl<sub>2</sub>. Yield: 2.7 g (60%).

Example 46: *N*<sup>2</sup>-Isobutyryl-9-(2',3'-di-*O*-Benzoyl-5'-*O*-*t*-Butyldiphenylsilyl-6'-Deoxy-β-D-Allofuranosyl)guanine (12).

*N*<sup>2</sup>-Isobutyrylguanine (1.47 g, 11.2 mmol) was suspended in mixture of hexamethyldisilazane (100 mL) and pyridine (50 mL) and boiled under reflux until complete dissolution (6 h) occurred, and then for an additional hour. The reaction mixture was cooled to RT evaporated to dryness and coevaporated with dry toluene (2 x 50 mL). To the residue was added a

- solution of acetates **8** (3.4 g, 5.3 mmol) in dry CH<sub>3</sub>CN (100 mL) followed by CF<sub>3</sub>SO<sub>3</sub>SiMe<sub>3</sub> (6.22 g, 28.0 mmol). The reaction mixture was boiled under reflux for 8 h, cooled to RT, concentrated to 1/3 of its original volume, diluted with CH<sub>2</sub>Cl<sub>2</sub> (100 mL) and extracted with sat. NaHCO<sub>3</sub> (2 x 50 mL),  
5 brine (2 x 50 mL) dried over MgSO<sub>4</sub> and evaporated to dryness. The product **12** was purified by flash chromatography using a gradient of 0-2% MeOH in CH<sub>2</sub>Cl<sub>2</sub>. Yield: 2.1g (54%).

Example 47: *N*<sup>6</sup>-Benzoyl-9-(2',3'-di-*O*-benzoyl-6'-Deoxy-β-D-Allofuranosyl)adenine (**15**).

- 10 Nucleoside **11** (1.65 g, 2.0 mmol) was dissolved in THF (50 mL) and a 1 M solution of TBAF in THF (4 mL) was added. The reaction mixture was kept at RT for 4 h, evaporated to dryness and the product purified by flash chromatography using a gradient of 0-5% MeOH in CH<sub>2</sub>Cl<sub>2</sub> to yield 1.0 g (85%) of compound **15**.

- 15 Example 48: *N*<sup>6</sup>-Benzoyl-9-(2',3'-di-*O*-Benzoyl-5'-*O*-Dimethoxytrityl-6'-Deoxy-β-D-Allofuranosyl)adenine (**19**).

- Nucleoside **15** (0.55 g, 0.92 mmol) was dissolved in dry CH<sub>2</sub>Cl<sub>2</sub> (50 mL). AgNO<sub>3</sub> (0.34 g, 2.0 mmol), dimethoxytrityl chloride (0.68 g, 2.0 mmol) and sym-collidine (0.48 g) were added under Ar. The reaction mixture was  
20 stirred for 2h, diluted with CH<sub>2</sub>Cl<sub>2</sub> (100 mL), filtered, evaporated to dryness and coevaporated with toluene (2 x 50 mL). Purification by flash chromatography using a gradient of 0-5% MeOH in CH<sub>2</sub>Cl<sub>2</sub> yielded 0.8 g (97%) of compound **19**.

- 25 Example 49: *N*<sup>6</sup>-Benzoyl-9-(5'-*O*-Dimethoxytrityl-6'-Deoxy-β-D-Allofuranosyl)adenine (**23**).

- Nucleoside **19** (1.8 g, 2 mmol) was dissolved in dioxane (50 mL), cooled to 0 °C and 2 M NaOH (50 mL) was added. The reaction mixture was kept at 0 °C for 45 m, neutralized with Dowex 50 (Pyr<sup>+</sup> form), filtered and the resin was washed with MeOH (2 x 50 mL). The filtrate was then  
30 evaporated to dryness. Purification by flash chromatography using a gradient of 0-10% MeOH in CH<sub>2</sub>Cl<sub>2</sub> yielded 1.1 g (80%) of **23**.



Example 50: N<sup>6</sup>-Benzoyl-9-(-5'-O-Dimethoxytrityl-2'-O-t-butylidimethylsilyl-6'-Deoxy-β-D-Allofuranosyl)adenine (27).

Nucleoside 23 (1.2 g, 1.8 mmol) was dissolved in dry THF (50 mL). Pyridine (0.50 g, 8 mmol) and AgNO<sub>3</sub> (0.4 g, 2.3 mmol) were added. After the AgNO<sub>3</sub> dissolved (1.5 h), t-butylidimethylsilyl chloride (0.35 g, 2.3 mmol) was added and the reaction mixture was stirred at RT for 16 h. The reaction mixture was diluted with CH<sub>2</sub>Cl<sub>2</sub> (100 mL), filtered into sat. NaHCO<sub>3</sub> (50 mL), extracted, the organic layer washed with brine (2 x 50 mL), dried over MgSO<sub>4</sub> and evaporated to dryness. The product 27 was purified by flash chromatography using a hexanes:EtOAc / 7:3 gradient. Yield: 0.7 g (50%).

Example 51: N<sup>6</sup>-Benzoyl-9-(-5'-O-Dimethoxytrityl-2'-O-t-butylidimethylsilyl-6'-Deoxy-β-D-Allofuranosyl)adenine-3'-(2-Cyanoethyl N,N-diisopropylphosphoramidite) (31).

Standard phosphitylation of 27 according to Scaringe, S.A.; Franklyn, C.; Usman, N. *Nucleic Acids Res.* 1990, 18, 5433-5441 yielded phosphoramidite 31 in 73% yield.

Example 52: Methyl-5-O-p-Nitrobenzoyl-2,3-O-Isopropylidene-6-deoxy-β-L-Tallofuranoside (5)

Methylfuranoside 4 (3.1 g 14.2 mmol) was dissolved in dry dioxane (200 mL), p-nitrobenzoic acid (10.0 g, 60 mmol) and triphenylphosphine (15.74 g, 60.0 mmol) were added followed by DEAD (10.45 g, 60.0 mmol). The reaction mixture was left at RT for 16 h, EtOH (5 mL) was added, and after 0.5 h the reaction mixture was evaporated to dryness. The residue was dissolved in CH<sub>2</sub>Cl<sub>2</sub> (300 mL) washed with sat. NaHCO<sub>3</sub> (2 x 75 mL), brine (2 x 75 mL) dried over MgSO<sub>4</sub> and evaporated to dryness. Purification by flash chromatography using a hexanes:EtOAc / 9:1 gradient yielded 4.1 g (78%) of compound 33. Subsequent debenzoylation (NaOMe/MeOH) and silylation (see preparation of 5) led to L-talofuranoside 34 which was converted to phosphoramidites 58-61 using the same methodology as described above for the preparation of the phosphoramidites of the D-allo-isomers 29-32.

The alkyl substituted nucleotides of this invention can be used to form stable oligonucleotides as discussed above for use in enzymatic cleavage

or antisense situations. Such oligonucleotides can be formed enzymatically using triphosphate forms by standard procedure. Administration of such oligonucleotides is by standard procedure. See Sullivan et al., PCT WO 94/ 02595.

- 5       The ribozymes and the target RNA containing site O were synthesized, deprotected and purified as described above. RNA cleavage assay was carried out at 37°C in the presence of 10 mM MgCl<sub>2</sub> as described above.

- 10       Applicant has substituted 5'-C-Me-L-talo nucleotides at positions A6, A9, A9 + G10, C11.1 and C11.1 + G10, as shown in Figure 78 (HH-O1 to HH-05). HH-O 1,2,4 and 5 showed almost wild type activity (Figure 79). However, HH-03 demonstrated low catalytic activity. Ribozymes HH-01, 2, 3, 4 and 5 are also extremely resistant to degradation by human serum nucleases.

15       Oligonucleotides with 2'-Deoxy-2'-Alkyl nucleotide

- 20       This invention uses 2'-deoxy-2'-alkyl nucleotides in oligonucleotides, which are particularly useful for enzymatic cleavage of RNA or single-stranded DNA, and also as antisense oligonucleotides. As the term is used in this application, 2'-deoxy-2'-alkyl nucleotide-containing enzymatic nucleic acids are catalytic nucleic molecules that contain 2'-deoxy-2'-alkyl nucleotide components replacing, but not limited to, double stranded stems, single stranded "catalytic core" sequences, single-stranded loops or single-stranded recognition sequences. These molecules are able to cleave (preferably, repeatedly cleave) separate RNA or DNA molecules in a nucleotide base sequence specific manner. Such catalytic nucleic acids can also act to cleave intramolecularly if that is desired. Such enzymatic molecules can be targeted to virtually any RNA transcript.

- 30       Also within the invention are 2'-deoxy-2'-alkyl nucleotides which may be present in enzymatic nucleic acid or even in antisense oligonucleotides. Contrary to the findings of De Mesmaeker *et al.* applicant has found that such nucleotides are useful since they enhance the stability of the antisense or enzymatic molecule, and can be used in locations which do not affect the desired activity of the molecule. That is, while the presence of the 2'-alkyl group may reduce binding affinity of the oligonucleotide containing this modification, if that moiety is not in an essential base pair
- 35

forming region then the enhanced stability that it provides to the molecule is advantageous. In addition, while the reduced binding may reduce enzymatic activity, the enhanced stability may make the loss of activity of less consequence. Thus, for example, if a 2'-deoxy-2'-alkyl-containing molecule has 10% the activity of the unmodified molecule, but has 10-fold higher stability *in vivo* then it has utility in the present invention. The same analysis is true for antisense oligonucleotides containing such modifications. The invention also relates to novel intermediates useful in the synthesis of such nucleotides and oligonucleotides (examples of which are shown in the Figures), and to methods for their synthesis.

Thus, in one aspect, the invention features 2'-deoxy-2'-alkylnucleotides, that is a nucleotide base having at the 2'-position on the sugar molecule an alkyl moiety and in preferred embodiments features those where the nucleotide is not uridine or thymidine. That is, the invention preferably includes all those nucleotides useful for making enzymatic nucleic acids or antisense molecules that are not described by the art discussed above.

Examples of various alkyl groups useful in this invention are shown in Figure 81, where each R group is any alkyl. The term "alkyl" does not include alkoxy groups which have an "-O-alkyl" group, where "alkyl" is defined as described above, where the O is adjacent the 2'-position of the sugar molecule.

In other aspects, also related to those discussed above, the invention features oligonucleotides having one or more 2'-deoxy-2'-alkylnucleotides (preferably not a 2'-alkyl- uridine or thymidine); e.g. enzymatic nucleic acids having a 2'-deoxy-2'-alkylnucleotide; and a method for producing an enzymatic nucleic acid molecule having enhanced activity to cleave an RNA or single-stranded DNA molecule, by forming the enzymatic molecule with at least one nucleotide having at its 2'-position an alkyl group. In other related aspects, the invention features 2'-deoxy-2'-alkylnucleotide triphosphates. These triphosphates can be used in standard protocols to form useful oligonucleotides of this invention.

The 2'-alkyl derivatives of this invention provide enhanced stability to the oligonucleotides containing them. While they may also reduce absolute activity in an *in vitro* assay they will provide enhanced overall

activity *in vivo*. Below are provided assays to determine which such molecules are useful. Those in the art will recognize that equivalent assays can be readily devised.

In another aspect, the invention features hammerhead motifs having enzymatic activity having ribonucleotides at locations shown in Figure 80 at 5, 6, 8, 12, and 15.1, and having substituted ribonucleotides at other positions in the core and in the substrate binding arms if desired. (The term "core" refers to positions between bases 3 and 14 in Figure 80, and the binding arms correspond to the bases from the 3'-end to base 15.1, and from the 5'-end to base 2). Applicant has found that use of ribonucleotides at these five locations in the core provide a molecule having sufficient enzymatic activity even when modified nucleotides are present at other sites in the motif. Other such combinations of useful ribonucleotides can be determined as described by Usman *et al. supra*.

Figure 80 shows base numbering of a hammerhead motif in which the numbering of various nucleotides in a hammerhead ribozyme is provided. This is not to be taken as an indication that the Figure is prior art to the pending claims, or that the art discussed is prior art to those claims. Referring to Figure 80 the preferred sequence of a hammerhead ribozyme in a 5'- to 3'-direction of the catalytic core is CUGANGAG[base paired with]CGAAA. In this invention, the use of 2'-C-alkyl substituted nucleotides that maintain or enhance the catalytic activity and or nuclease resistance of the hammerhead ribozyme is described. Although substitutions of any nucleotide with any of the modified nucleotides shown in Figure 81 are possible, and were indeed synthesized, the basic structure composed of primarily 2'-O-Me nucleotides with selected substitutions was chosen to maintain maximal catalytic activity (Yang *et al. Biochemistry* 1992, 31, 5005-5009 and Paoletta *et al. , EMBO J.* 1992, 11, 1913-1919) and ease of synthesis, but is not limiting to this invention.

Ribozymes from Figure 80 and Table 45 were synthesized and assayed for catalytic activity and nuclease resistance. With the exception of entries 8 and 17, all of the modified ribozymes retained at least 1/10 of the wild-type catalytic activity. From Table 45, all 2'-modified ribozymes showed very large and significant increases in stability in human serum (shown) and in the other fluids described below (Example 55, data not shown). The order of most aggressive nuclease activity was fetal bovine

serum, > human serum > human plasma > human synovial fluid. As an overall measure of the effect of these 2'-substitutions on stability and activity, a ratio  $\beta$  was calculated (Table 45). This  $\beta$  value indicated that all modified ribozymes tested had significant, >100 - >1700 fold, increases in overall stability and activity. These increases in  $\beta$  indicate that the lifetime of these modified ribozymes *in vivo* are significantly increased which should lead to a more pronounced biological effect.

More general substitutions of the 2'-modified nucleotides from Figure 81 also increased the  $t_{1/2}$  of the resulting modified ribozymes. However the catalytic activity of these ribozymes was decreased > 10-fold.

In Figure 86 compound 37 may be used as a general intermediate to prepare derivatized 2'-alkyl phosphoramidites, where X is CH<sub>3</sub>, or an alkyl, or other group described above.

The following are non-limiting examples showing the synthesis of nucleic acids using 2'-alkyl substituted phosphoramidites, the syntheses of the amidites, their testing for enzymatic activity and nuclease resistance.

Example 53: Synthesis of Hammerhead Ribozymes Containing 2'-Deoxy-2'-Alkyl nucleotides & Other 2'-Modified Nucleotides

The method of synthesis used generally follows the procedure for normal RNA synthesis as described in Usman, N.; Ogilvie, K.K.; Jiang, M.-Y.; Cedergren, R.J. *J. Am. Chem. Soc.* 1987, 109, 7845-7854 and in Scaringe, S.A.; Franklyn, C.; Usman, N. *Nucleic Acids Res.* 1990, 18, 5433-5441 and makes use of common nucleic acid protecting and coupling groups, such as dimethoxytrityl at the 5'-end, and phosphoramidites at the 3'-end (compounds 10, 12, 17, 22, 31, 18, 26, 32, 36 and 38). Other 2'-modified phosphoramidites were prepared according to: 3 & 4, Eckstein *et al.* *International Publication* No. WO 92/07065; and 5 Kois *et al.* *Nucleosides & Nucleotides* 1993, 12, 1093-1109. The average stepwise coupling yields were ~98%. The 2'-substituted phosphoramidites were incorporated into hammerhead ribozymes as shown in Figure 80. However, these 2'-alkyl substituted phosphoramidites may be incorporated not only into hammerhead ribozymes, but also into hairpin, hepatitis delta virus, Group I or Group II intron catalytic nucleic acids, or into antisense

oligonucleotides. They are, therefore, of general use in any nucleic acid structure.

Example 54: Ribozyme Activity Assay

Purified 5'-end labeled RNA substrates (15-25-mers) and purified 5'-  
5 end labeled ribozymes (~36-mers) were both heated to 95 °C, quenched  
on ice and equilibrated at 37 °C, separately. Ribozyme stock solutions  
were 1 mM, 200 nM, 40 nM or 8 nM and the final substrate RNA  
concentrations were ~ 1 nM. Total reaction volumes were 50 µL. The  
assay buffer was 50 mM Tris-Cl, pH 7.5 and 10 mM MgCl<sub>2</sub>. Reactions were  
10 initiated by mixing substrate and ribozyme solutions at t = 0. Aliquots of 5  
mL were removed at time points of 1, 5, 15, 30, 60 and 120 m. Each time  
point was quenched in formamide loading buffer and loaded onto a 15%  
denaturing polyacrylamide gel for analysis. Quantitative analyses were  
performed using a phosphorimager (Molecular Dynamics).

15 Example 55: Stability Assay

500 pmol of gel-purified 5'-end-labeled ribozymes were precipitated  
in ethanol and pelleted by centrifugation. Each pellet was resuspended in  
20 µL of appropriate fluid (human serum, human plasma, human synovial  
fluid or fetal bovine serum) by vortexing for 20 s at room temperature. The  
20 samples were placed into a 37 °C incubator and 2 µL aliquots were  
withdrawn after incubation for 0, 15, 30, 45, 60, 120, 240 and 480 m.  
Aliquots were added to 20 µL of a solution containing 95% formamide and  
0.5X TBE (50 mM Tris, 50 mM borate, 1 mM EDTA) to quench further  
nuclease activity and the samples were frozen until loading onto gels.  
25 Ribozymes were size-fractionated by electrophoresis in 20%  
acrylamide/8M urea gels. The amount of intact ribozyme at each time point  
was quantified by scanning the bands with a phosphorimager (Molecular  
Dynamics) and the half-life of each ribozyme in the fluids was determined  
by plotting the percent intact ribozyme vs the time of incubation and  
30 extrapolation from the graph.

Example 56: 3',5'-O-(Tetraisopropyl-disiloxane-1,3-diyl)-2'-O-Phenoxythio-  
carbonyl-Uridine (7)

To a stirred solution of 3',5'-O-(tetraisopropyl-disiloxane-1,3-diyl)-  
uridine, 6, (15.1 g, 31 mmol, synthesized according to *Nucleic Acid*

Chemistry, ed. Leroy Townsend, 1986 pp. 229-231) and dimethylamino-pyridine (7.57 g, 62 mmol) a solution of phenylchlorothionoformate (5.15 mL, 37.2 mmol) in 50 mL of acetonitrile was added dropwise and the reaction stirred for 8 h. TLC (EtOAc:hexanes / 1:1) showed disappearance of the starting material. The reaction mixture was evaporated, the residue dissolved in chloroform, washed with water and brine, the organic layer was dried over sodium sulfate, filtered and evaporated to dryness. The residue was purified by flash chromatography on silica gel with EtOAc:hexanes / 2:1 as eluent to give 16.44 g (85%) of 7.

10 Example 57: 3',5'-O-(Tetraisopropyl-disiloxane-1,3-diyl)-2'-C-Allyl -Uridine (8)

To a refluxing, under argon, solution of 3',5'-O-(tetraisopropyl-disiloxane-1,3-diyl)-2'-O-phenoxythiocarbonyl-uridine, 7, (5 g, 8.03 mmol) and allyltributyltin (12.3 mL, 40.15 mmol) in dry toluene, benzoyl peroxide (0.5 g) was added portionwise during 1 h. The resulting mixture was allowed to reflux under argon for an additional 7-8 h. The reaction was then evaporated and the product 8 purified by flash chromatography on silica gel with EtOAc:hexanes / 1:3 as eluent. Yield 2.82 g (68.7%).

Example 58: 5'-O-Dimethoxytrityl-2'-C-Allyl-Uridine (9)

20 A solution of 8 (1.25 g, 2.45 mmol) in 10 mL of dry tetrahydrofuran (THF) was treated with a 1 M solution of tetrabutylammoniumfluoride in THF (3.7 mL) for 10 m at room temperature. The resulting mixture was evaporated, the residue was loaded onto a silica gel column, washed with 1 L of chloroform, and the desired deprotected compound was eluted with 25 chloroform:methanol / 9:1. Appropriate fractions were combined, solvents removed by evaporation, and the residue was dried by coevaporation with dry pyridine. The oily residue was redissolved in dry pyridine, dimethoxytritylchloride (1.2 eq) was added and the reaction mixture was left under anhydrous conditions overnight. The reaction was quenched with methanol (20 mL), evaporated, dissolved in chloroform, washed with 30 5% aq. sodium bicarbonate and brine. The organic layer was dried over sodium sulfate and evaporated. The residue was purified by flash chromatography on silica gel, EtOAc:hexanes / 1:1 as eluent, to give 0.85 g (57%) of 9 as a white foam.

Example 59: 5'-O-Dimethoxytrityl-2'-C-Allyl-Uridine 3'-(2-Cyanoethyl N,N-diisopropylphosphoramidite) (10)

5'-O-Dimethoxytrityl-2'-C-allyl-uridine (0.64 g, 1.12 mmol) was dissolved in dry dichloromethane under dry argon. N,N-Diisopropylethylamine (0.39 mL, 2.24 mmol) was added and the solution was ice-cooled. 2-Cyanoethyl N,N-diisopropylchlorophosphoramidite (0.35 mL, 1.57 mmol) was added dropwise to the stirred reaction solution and stirring was continued for 2 h at RT. The reaction mixture was then ice-cooled and quenched with 12 mL of dry methanol. After stirring for 5 m, the mixture was concentrated *in vacuo* (40 °C) and purified by flash chromatography on silica gel using a gradient of 10-60% EtOAc in hexanes containing 1% triethylamine mixture as eluent. Yield: 0.78 g (90%), white foam.

Example 60: 3',5'-O-(Tetraisopropyl-disiloxane-1,3-diyl)-2'-C-Allyl-N<sup>4</sup>-Acetyl-Cytidine (11)

Triethylamine (6.35 mL, 45.55 mmol) was added dropwise to a stirred ice-cooled mixture of 1,2,4-triazole (5.66 g, 81.99 mmol) and phosphorous oxychloride (0.86 mL, 9.11 mmol) in 50 mL of anhydrous acetonitrile. To the resulting suspension a solution of 3',5'-O-(tetraisopropyl-disiloxane-1,3-diyl)-2'-C-allyl uridine (2.32 g, 4.55 mmol) in 30 mL of acetonitrile was added dropwise and the reaction mixture was stirred for 4 h at room temperature. The reaction was concentrated *in vacuo* to a minimal volume (not to dryness). The residue was dissolved in chloroform and washed with water, saturated aq. sodium bicarbonate and brine. The organic layer was dried over sodium sulfate and the solvent was removed *in vacuo*. The resulting foam was dissolved in 50 mL of 1,4-dioxane and treated with 29% aq. NH<sub>4</sub>OH overnight at room temperature. TLC (chloroform:methanol / 9:1) showed complete conversion of the starting material. The solution was evaporated, dried by coevaporation with anhydrous pyridine and acetylated with acetic anhydride (0.52 mL, 5.46 mmol) in pyridine overnight. The reaction mixture was quenched with methanol, evaporated, the residue was dissolved in chloroform, washed with sodium bicarbonate and brine. The organic layer was dried over sodium sulfate, evaporated to dryness and purified by flash chromatography on silica gel (3% MeOH in chloroform). Yield 2.3 g (90%) as a white foam.



Example 61: 5'-O-Dimethoxytrityl-2'-C-Allyl-N<sup>4</sup>-Acetyl-Cytidine

This compound was obtained analogously to the uridine derivative 9 in 55% yield.

Example 62: 5'-O-Dimethoxytrityl-2'-C-allyl-N<sup>4</sup>-Acetyl-Cytidine 3'-(2-Cyanoethyl N,N-diisopropylphosphoramidite) (12)

2'-O-Dimethoxytrityl-2'-C-allyl-N<sup>4</sup>-acetyl cytidine (0.8 g, 1.31 mmol) was dissolved in dry dichloromethane under argon. N,N-Diisopropylethylamine (0.46 mL, 2.62 mmol) was added and the solution was ice-cooled. 2-Cyanoethyl N,N-diisopropylchlorophosphoramidite (0.38 mL, 1.7 mmol) was added dropwise to a stirred reaction solution and stirring was continued for 2 h at room temperature. The reaction mixture was then ice-cooled and quenched with 12 mL of dry methanol. After stirring for 5 m, the mixture was concentrated *in vacuo* (40 °C) and purified by flash chromatography on silica gel using chloroform:ethanol / 98:2 with 2% triethylamine mixture as eluent. Yield: 0.91 g (85%), white foam.

Example 63: 2'-Deoxy-2'-Methylene-Uridine

2'-Deoxy-2'-methylene-3',5'-O-(tetraisopropylidisiloxane-1,3-diyl)-uridine **14** (Hansske, F.; Madej, D.; Robins, M. J. *Tetrahedron* 1984, 40, 125 and Matsuda, A.; Takenuki, K.; Tanaka, S.; Sasaki, T.; Ueda, T. *J. Med. Chem.* 1991, 34, 812) (2.2 g, 4.55 mmol) dissolved in THF (20 mL) was treated with 1 M TBAF in THF (10 mL) for 20 m and concentrated *in vacuo*. The residue was triturated with petroleum ether and chromatographed on a silica gel column. 2'-Deoxy-2'-methylene-uridine (1.0 g, 3.3 mmol, 72.5%) was eluted with 20% MeOH in CH<sub>2</sub>Cl<sub>2</sub>.

Example 64: 5'-O-DMT-2'-Deoxy-2'-Methylene-Uridine (15)

2'-Deoxy-2'-methylene-uridine (0.91 g, 3.79 mmol) was dissolved in pyridine (10 mL) and a solution of DMT-Cl in pyridine (10 mL) was added dropwise over 15 m. The resulting mixture was stirred at RT for 12 h and MeOH (2 mL) was added to quench the reaction. The mixture was concentrated *in vacuo* and the residue taken up in CH<sub>2</sub>Cl<sub>2</sub> (100 mL) and washed with sat. NaHCO<sub>3</sub>, water and brine. The organic extracts were dried over MgSO<sub>4</sub>, concentrated *in vacuo* and purified over a silica gel column using EtOAc:hexanes as eluant to yield **15** (0.43 g, 0.79 mmol, 22%).

Example 65: 5'-O-DMT-2'-Deoxy-2'-Methylene-Uridine 3'-(2-Cyanoethyl N,N-diisopropylphosphoramidite) (17)

1-(2'-Deoxy-2'-methylene-5'-O-dimethoxytrityl-β-D-ribofuranosyl)-uracil (0.43 g, 0.8 mmol) dissolved in dry CH<sub>2</sub>Cl<sub>2</sub> (15 mL) was placed in a  
5 round-bottom flask under Ar. Diisopropylethylamine (0.28 mL, 1.6 mmol) was added, followed by the dropwise addition of 2-cyanoethyl N,N-diisopropylchlorophosphoramidite (0.25 mL, 1.12 mmol). The reaction mixture was stirred 2 h at RT and quenched with ethanol (1 mL). After 10 m the mixture evaporated to a syrup *in vacuo* (40 °C). The product (0.3 g, 0.4  
10 mmol, 50%) was purified by flash column chromatography over silica gel using a 25-70% EtOAc gradient in hexanes, containing 1% triethylamine, as eluant. R<sub>f</sub> 0.42 (CH<sub>2</sub>Cl<sub>2</sub>: MeOH / 15:1)

Example 66: 2'-Deoxy-2'-Difluoromethylene-3',5'-O-(Tetraisopropylidisiloxane-1,3-diyl)-Uridine

15 2'-Keto-3',5'-O-(tetraisopropylidisiloxane-1,3-diyl)uridine **14** (1.92 g, 12.6 mmol) and triphenylphosphine (2.5 g, 9.25 mmol) were dissolved in diglyme (20 mL), and heated to a bath temperature of 160 °C. A warm (60 °C) solution of sodium chlorodifluoroacetate in diglyme (50 mL) was added (dropwise from an equilibrating dropping funnel) over a period of ~1 h. The  
20 resulting mixture was further stirred for 2 h and concentrated *in vacuo*. The residue was dissolved in CH<sub>2</sub>Cl<sub>2</sub> and chromatographed over silica gel. 2'-Deoxy-2'-difluoromethylene-3',5'-O-(tetraisopropylidisiloxane-1,3-diyl)-uridine (3.1 g, 5.9 mmol, 70%) eluted with 25% hexanes in EtOAc.

Example 67: 2'-Deoxy-2'-Difluoromethylene-Uridine

25 2'-Deoxy-2'-methylene-3',5'-O-(tetraisopropylidisiloxane-1,3-diyl)-uridine (3.1 g, 5.9 mmol) dissolved in THF (20 mL) was treated with 1 M TBAF in THF (10 mL) for 20 m and concentrated *in vacuo*. The residue was triturated with petroleum ether and chromatographed on silica gel column. 2'-Deoxy-2'-difluoromethylene-uridine (1.1 g, 4.0 mmol, 68%) was eluted  
30 with 20% MeOH in CH<sub>2</sub>Cl<sub>2</sub>.

Example 68: 5'-O-DMT-2'-Deoxy-2'-Difluoromethylene-Uridine (16)

2'-Deoxy-2'-difluoromethylene-uridine (1.1 g, 4.0 mmol) was dissolved in pyridine (10 mL) and a solution of DMT-Cl (1.42 g, 4.18 mmol) in pyridine (10 mL) was added dropwise over 15 m. The resulting mixture

- was stirred at RT for 12 h and MeOH (2 mL) was added to quench the reaction. The mixture was concentrated *in vacuo* and the residue taken up in CH<sub>2</sub>Cl<sub>2</sub> (100 mL) and washed with sat. NaHCO<sub>3</sub>, water and brine. The organic extracts were dried over MgSO<sub>4</sub>, concentrated *in vacuo* and purified over a silica gel column using 40% EtOAc:hexanes as eluant to yield 5'-O-DMT-2'-deoxy-2'-difluoromethylene-uridine 16 (1.05 g, 1.8 mmol, 45%).

Example 69: 5'-O-DMT-2'-Deoxy-2'-Difluoromethylene-Uridine 3'-(2-Cyanoethyl N,N-diisopropylphosphoramidite) (18)

- 1-(2'-Deoxy-2'-difluoromethylene-5'-O-dimethoxytrityl-β-D-ribofuranosyl)-uracil (0.577 g, 1 mmol) dissolved in dry CH<sub>2</sub>Cl<sub>2</sub> (15 mL) was placed in a round-bottom flask under Ar. Diisopropylethylamine (0.36 mL, 2 mmol) was added, followed by the dropwise addition of 2-cyanoethyl N,N-diisopropylchlorophosphoramidite (0.44 mL, 1.4 mmol). The reaction mixture was stirred for 2 h at RT and quenched with ethanol (1 mL). After 10 m the mixture evaporated to a syrup *in vacuo* (40 °C). The product (0.404 g, 0.52 mmol, 52%) was purified by flash chromatography over silica gel using 20-50% EtOAc gradient in hexanes, containing 1% triethylamine, as eluant. R<sub>f</sub> 0.48 (CH<sub>2</sub>Cl<sub>2</sub>: MeOH / 15:1).

Example 70: 2'-Deoxy-2'-Methylene-3',5'-O-(Tetraisopropylidisiloxane-1,3-diyl)-4-N-Acetyl-Cytidine 20

- Triethylamine (4.8 mL, 34 mmol) was added to a solution of POCl<sub>3</sub> (0.65 mL, 6.8 mmol) and 1,2,4-triazole (2.1 g, 30.6 mmol) in acetonitrile (20 mL) at 0 °C. A solution of 2'-deoxy-2'-methylene-3',5'-O-(tetraisopropylidisiloxane-1,3-diyl) uridine 19 (1.65 g, 3.4 mmol) in acetonitrile (20 mL) was added dropwise to the above reaction mixture and left to stir at room temperature for 4 h. The mixture was concentrated *in vacuo*, dissolved in CH<sub>2</sub>Cl<sub>2</sub> (2 x 100 mL) and washed with 5% NaHCO<sub>3</sub> (1 x 100 mL). The organic extracts were dried over Na<sub>2</sub>SO<sub>4</sub> concentrated *in vacuo*, dissolved in dioxane (10 mL) and aq. ammonia (20 mL). The mixture was stirred for 12 h and concentrated *in vacuo*. The residue was azeotroped with anhydrous pyridine (2 x 20 mL). Acetic anhydride (3 mL) was added to the residue dissolved in pyridine, stirred at RT for 4 h and quenched with sat. NaHCO<sub>3</sub> (5 mL). The mixture was concentrated *in vacuo*, dissolved in CH<sub>2</sub>Cl<sub>2</sub> (2 x 100 mL) and washed with 5% NaHCO<sub>3</sub> (1 x 100 mL). The

organic extracts were dried over  $\text{Na}_2\text{SO}_4$ , concentrated *in vacuo* and the residue chromatographed over silica gel. 2'-Deoxy-2'-methylene-3',5'-O-(tetraisopropylidisiloxane-1,3-diyl)-4-N-acetyl-cytidine 20 (1.3 g, 2.5 mmol, 73%) was eluted with 20% EtOAc in hexanes.

5 Example 71: 1-(2'-Deoxy-2'-Methylene-5'-O-Dimethoxytrityl-β-D-ribofuranosyl)-4-N-Acetyl-Cytosine 21

2'-Deoxy-2'-methylene-3',5'-O-(tetraisopropylidisiloxane-1,3-diyl)-4-N-acetyl-cytidine 20 (1.3 g, 2.5 mmol) dissolved in THF (20 mL) was treated with 1 M TBAF in THF (3 mL) for 20 m and concentrated *in vacuo*. The residue was triturated with petroleum ether and chromatographed on silica gel column. 2'-Deoxy-2'-methylene-4-N-acetyl-cytidine (0.56 g, 1.99 mmol, 80%) was eluted with 10% MeOH in  $\text{CH}_2\text{Cl}_2$ . 2'-Deoxy-2'-methylene-4-N-acetyl-cytidine (0.56 g, 1.99 mmol) was dissolved in pyridine (10 mL) and a solution of DMT-Cl (0.81 g, 2.4 mmol) in pyridine (10 mL) was added dropwise over 15 m. The resulting mixture was stirred at RT for 12 h and MeOH (2 mL) was added to quench the reaction. The mixture was concentrated *in vacuo* and the residue taken up in  $\text{CH}_2\text{Cl}_2$  (100 mL) and washed with sat.  $\text{NaHCO}_3$  (50 mL), water (50 mL) and brine (50 mL). The organic extracts were dried over  $\text{MgSO}_4$ , concentrated *in vacuo* and purified over a silica gel column using EtOAc:hexanes / 60:40 as eluant to yield 21 (0.88 g, 1.5 mmol, 75%).

Example 72: 1-(2'-Deoxy-2'-Methylene-5'-O-Dimethoxytrityl-β-D-ribofuranosyl)-4-N-Acetyl-Cytosine 3'-(2-Cyanoethyl-N,N-diisopropylphosphoramidite) (22)

1-(2'-Deoxy-2'-methylene-5'-O-dimethoxytrityl-β-D-ribofuranosyl)-4-N-acetyl-cytosine 21 (0.88 g, 1.5 mmol) dissolved in dry  $\text{CH}_2\text{Cl}_2$  (10 mL) was placed in a round-bottom flask under Ar. Diisopropylethylamine (0.8 mL, 4.5 mmol) was added, followed by the dropwise addition of 2-cyanoethyl N,N-diisopropylchlorophosphoramidite (0.4 mL, 1.8 mmol). The reaction mixture was stirred 2 h at room temperature and quenched with ethanol (1 mL). After 10 m the mixture evaporated to a syrup *in vacuo* (40 °C). The product 22 (0.82 g, 1.04 mmol, 69%) was purified by flash chromatography over silica gel using 50-70% EtOAc gradient in hexanes, containing 1% triethylamine, as eluant.  $R_f$  0.36 ( $\text{CH}_2\text{Cl}_2$ :MeOH / 20:1).

Example 73: 2'-Deoxy-2'-difluoromethylene-3',5'-O-(Tetraisopropyl  
disiloxane-1,3-diyl)-4-N-Acetyl-Cytidine (24)

- Et<sub>3</sub>N (6.9 mL, 50 mmol) was added to a solution of POCl<sub>3</sub> (0.94 mL, 10 mmol) and 1,2,4-triazole (3.1 g, 45 mmol) in acetonitrile (20 mL) at 0 °C.
- 5 A solution of 2'-deoxy-2'-difluoromethylene-3',5'-O-(tetraisopropylidisiloxane-1,3-diyl)uridine 23 ([described in example 14] 2.6 g, 5 mmol) in acetonitrile (20 mL) was added dropwise to the above reaction mixture and left to stir at RT for 4 h. The mixture was concentrated *in vacuo*, dissolved in CH<sub>2</sub>Cl<sub>2</sub> (2 x 100 mL) and washed with 5% NaHCO<sub>3</sub> (1 x 100 mL). The
- 10 organic extracts were dried over Na<sub>2</sub>SO<sub>4</sub> concentrated *in vacuo*, dissolved in dioxane (20 mL) and aq. ammonia (30 mL). The mixture was stirred for 12 h and concentrated *in vacuo*. The residue was azeotroped with anhydrous pyridine (2 x 20 mL). Acetic anhydride (5 mL) was added to the residue dissolved in pyridine, stirred at RT for 4 h and quenched with sat.
- 15 NaHCO<sub>3</sub> (5mL). The mixture was concentrated *in vacuo*, dissolved in CH<sub>2</sub>Cl<sub>2</sub> (2 x 100 mL) and washed with 5% NaHCO<sub>3</sub> (1 x 100 mL). The organic extracts were dried over Na<sub>2</sub>SO<sub>4</sub>, concentrated *in vacuo* and the residue chromatographed over silica gel. 2'-Deoxy-2'-difluoromethylene-3',5'-O-(tetraisopropylidisiloxane-1,3-diyl)-4-N-acetyl-cytidine 24 (2.2 g, 3.9
- 20 mmol, 78%) was eluted with 20% EtOAc in hexanes.

Example 74: 1-(2'-Deoxy-2'-Difluoromethylene-5'-O-Dimethoxytrityl-β-D-  
ribofuranosyl)-4-N-Acetyl-Cytosine (25)

- 2'-Deoxy-2'-difluoromethylene-3',5'-O-(tetraisopropylidisiloxane-1,3-diyl)-4-N-acetyl-cytidine 24 (2.2 g, 3.9 mmol) dissolved in THF (20 mL) was
- 25 treated with 1 M TBAF in THF (3 mL) for 20 m and concentrated *in vacuo*. The residue was triturated with petroleum ether and chromatographed on a silica gel column. 2'-Deoxy-2'-difluoromethylene-4-N-acetyl-cytidine (0.89 g, 2.8 mmol, 72%) was eluted with 10% MeOH in CH<sub>2</sub>Cl<sub>2</sub>. 2'-Deoxy-2'-difluoromethylene-4-N-acetyl-cytidine (0.89 g, 2.8 mmol) was dissolved in
- 30 pyridine (10 mL) and a solution of DMT-Cl (1.03 g, 3.1 mmol) in pyridine (10 mL) was added dropwise over 15 m. The resulting mixture was stirred at RT for 12 h and MeOH (2 mL) was added to quench the reaction. The mixture was concentrated *in vacuo* and the residue taken up in CH<sub>2</sub>Cl<sub>2</sub> (100 mL) and washed with sat. NaHCO<sub>3</sub> (50 mL), water (50 mL) and brine
- 35 (50 mL). The organic extracts were dried over MgSO<sub>4</sub>, concentrated *in*

*vacuo* and purified over a silica gel column using EtOAc:hexanes / 60:40 as eluant to yield 25 (1.2 g, 1.9 mmol, 68%).

Example 75: 1-(2'-Deoxy-2'-Difluoromethylene-5'-O-Dimethoxytrityl-β-D-ribofuranosyl)-4-N-Acetylcytosine 3'-(2-cyanoethyl-N,N-diisopropylphosphoramidite) (26)

1-(2'-Deoxy-2'-difluoromethylene-5'-O-dimethoxytrityl-β-D-ribofuranosyl)-4-N-acetylcytosine 25 (0.6 g, 0.97 mmol) dissolved in dry CH<sub>2</sub>Cl<sub>2</sub> (10 mL) was placed in a round-bottom flask under Ar. Diisopropylethylamine (0.5 mL, 2.9 mmol) was added, followed by the dropwise addition of 2-cyanoethyl N,N-diisopropylchlorophosphoramidite (0.4 mL, 1.8 mmol). The reaction mixture was stirred 2 h at RT and quenched with ethanol (1 mL). After 10 m the mixture was evaporated to a syrup *in vacuo* (40 °C). The product 26, a white foam (0.52 g, 0.63 mmol, 65%) was purified by flash chromatography over silica gel using 30-70% EtOAc gradient in hexanes, containing 1% triethylamine, as eluant. R<sub>f</sub> 0.48 (CH<sub>2</sub>Cl<sub>2</sub>:MeOH / 20:1).

Example 76: 2'-Keto-3',5'-O-(Tetraisopropylidisiloxane-1,3-diyl)-6-N-(4-t-Butylbenzoyl)-Adenosine (28)

Acetic anhydride (4.6 mL) was added to a solution of 3',5'-O-(tetraisopropylidisiloxane-1,3-diyl)-6-N-(4-t-butylbenzoyl)-adenosine (Brown, J.; Christodolou, C.; Jones, S.; Modak, A.; Reese, C.; Sibanda, S.; Ubasawa A. *J. Chem. Soc. Perkin Trans. I* 1989, 1735) (6.2 g, 9.2 mmol) in DMSO (37 mL) and the resulting mixture was stirred at room temperature for 24 h. The mixture was concentrated *in vacuo*. The residue was taken up in EtOAc and washed with water. The organic layer was dried over MgSO<sub>4</sub> and concentrated *in vacuo*. The residue was purified on a silica gel column to yield 2'-keto-3',5'-O-(tetraisopropylidisiloxane-1,3-diyl)-6-N-(4-t-butylbenzoyl)-adenosine 28 (4.8 g, 7.2 mmol, 78%).

Example 77: 2'-Deoxy-2'-methylene-3',5'-O-(Tetraisopropylidisiloxane-1,3-diyl)-6-N-(4-t-Butylbenzoyl)-Adenosine (29)

Under a pressure of argon, sec-butyllithium in hexanes (11.2 mL, 14.6 mmol) was added to a suspension of triphenylmethylphosphonium iodide (7.07 g, 17.5 mmol) in THF (25 mL) cooled at -78 °C. The homogeneous orange solution was allowed to warm to -30 °C and a solution of 2'-keto-3',5'-O-(tetraisopropylidisiloxane-1,3-diyl)-6-N-(4-t-butylbenzoyl)-adenosine

- 28 (4.87 g, 7.3 mmol) in THF (25 mL) was transferred to this mixture under argon pressure. After warming to RT, stirring was continued for 24 h. THF was evaporated and replaced by CH<sub>2</sub>Cl<sub>2</sub> (250 mL), water was added (20 mL), and the solution was neutralized with a cooled solution of 2% HCl.
- 5 The organic layer was washed with H<sub>2</sub>O (20 mL), 5% aqueous NaHCO<sub>3</sub> (20 mL), H<sub>2</sub>O to neutrality, and brine (10 mL). After drying (Na<sub>2</sub>SO<sub>4</sub>), the solvent was evaporated *in vacuo* to give the crude compound, which was chromatographed on a silica gel column. Elution with light petroleum ether:EtOAc / 7:3 afforded pure 2'-deoxy-2'-methylene-3',5'-O-(tetraisopropylidisiloxane-1,3-diyl)-6-N-(4-*t*-butylbenzoyl)-adenosine 29 (3.86 g, 5.8 mmol, 79%).
- 10

Example 78: 2'-Deoxy-2'-Methylene-6-N-(4-*t*-Butylbenzoyl)-Adenosine

- 2'-Deoxy-2'-methylene-3',5'-O-(tetraisopropylidisiloxane-1,3-diyl)-6-N-(4-*t*-butylbenzoyl)-adenosine (3.86 g, 5.8 mmol) dissolved in THF (30 mL)
- 15 was treated with 1 M TBAF in THF (15 mL) for 20 m and concentrated *in vacuo*. The residue was triturated with petroleum ether and chromatographed on a silica gel column. 2'-Deoxy-2'-methylene-6-N-(4-*t*-butylbenzoyl)-adenosine (1.8 g, 4.3 mmol, 74%) was eluted with 10% MeOH in CH<sub>2</sub>Cl<sub>2</sub>.

- 20 Example 79: 5'-O-DMT-2'-Deoxy-2'-Methylene-6-N-(4-*t*-Butylbenzoyl)-Adenosine (29)

- 2'-Deoxy-2'-methylene-6-N-(4-*t*-butylbenzoyl)-adenosine (0.75 g, 1.77 mmol) was dissolved in pyridine (10 mL) and a solution of DMT-Cl (0.66 g, 1.98 mmol) in pyridine (10 mL) was added dropwise over 15 m.
- 25 The resulting mixture was stirred at RT for 12 h and MeOH (2 mL) was added to quench the reaction. The mixture was concentrated *in vacuo* and the residue taken up in CH<sub>2</sub>Cl<sub>2</sub> (100 mL) and washed with sat. NaHCO<sub>3</sub>, water and brine. The organic extracts were dried over MgSO<sub>4</sub>, concentrated *in vacuo* and purified over a silica gel column using 50% EtOAc:hexanes as an eluant to yield 29 (0.81 g, 1.1 mmol, 62%).
- 30

Example 80: 5'-O-DMT-2'-Deoxy-2'-Methylene-6-N-(4-*t*-Butylbenzoyl)-Adenosine 3'-(2-Cyanoethyl *N,N*-diisopropylphosphoramidite) (31)

1-(2'-Deoxy-2'-methylene-5'-O-dimethoxytrityl-β-D-ribofuranosyl)-6-N-(4-*t*-butylbenzoyl)-adenine 29 dissolved in dry CH<sub>2</sub>Cl<sub>2</sub> (15 mL) was placed

in a round bottom flask under Ar. Diisopropylethylamine was added, followed by the dropwise addition of 2-cyanoethyl *N,N*-diisopropylchlorophosphoramidite. The reaction mixture was stirred 2 h at RT and quenched with ethanol (1 mL). After 10 m the mixture was  
5 evaporated to a syrup *in vacuo* (40 °C). The product was purified by flash chromatography over silica gel using 30-50% EtOAc gradient in hexanes, containing 1% triethylamine, as eluant (0.7 g, 0.76 mmol, 68%). *R*<sub>f</sub> 0.45 (CH<sub>2</sub>Cl<sub>2</sub>: MeOH / 20:1)

10 Example 81: 2'-Deoxy-2'-Difluoromethylene-3',5'-O-(Tetraisopropylidisiloxane-1,3-diyl)-6-*N*-(4-*t*-Butylbenzoyl)-Adenosine

2'-Keto-3',5'-O-(tetraisopropylidisiloxane-1,3-diyl)-6-*N*-(4-*t*-butylbenzoyl)-adenosine **28** (6.7 g, 10 mmol) and triphenylphosphine (2.9 g, 11 mmol) were dissolved in diglyme (20 mL), and heated to a bath temperature of 160 °C. A warm (60 °C) solution of sodium  
15 chlorodifluoroacetate (2.3 g, 15 mmol) in diglyme (50 mL) was added (dropwise from an equilibrating dropping funnel) over a period of ~1 h. The resulting mixture was further stirred for 2 h and concentrated *in vacuo*. The residue was dissolved in CH<sub>2</sub>Cl<sub>2</sub> and chromatographed over silica gel. 2'-Deoxy-2'-difluoromethylene-3',5'-O-(tetraisopropylidisiloxane-1,3-diyl)-6-*N*-  
20 (4-*t*-butylbenzoyl)-adenosine (4.1g, 6.4 mmol, 64%) eluted with 15% hexanes in EtOAc.

Example 82: 2'-Deoxy-2'-Difluoromethylene-6-*N*-(4-*t*-Butylbenzoyl)-Adenosine

2'-Deoxy-2'-difluoromethylene-3',5'-O-(tetraisopropylidisiloxane-1,3-diyl)-6-*N*-(4-*t*-butylbenzoyl)-adenosine (4.1 g, 6.4 mmol) dissolved in THF  
25 (20 mL) was treated with 1 M TBAF in THF (10 mL) for 20 m and concentrated *in vacuo*. The residue was triturated with petroleum ether and chromatographed on a silica gel column. 2'-Deoxy-2'-difluoromethylene-6-*N*-(4-*t*-butylbenzoyl)-adenosine (2.3 g, 4.9 mmol, 77%) was eluted  
30 with 20% MeOH in CH<sub>2</sub>Cl<sub>2</sub>.

Example 83: 5'-O-DMT-2'-Deoxy-2'-Difluoromethylene-6-*N*-(4-*t*-Butylbenzoyl)-Adenosine (30)

2'-Deoxy-2'-difluoromethylene-6-*N*-(4-*t*-butylbenzoyl)-adenosine (2.3 g, 4.9 mmol) was dissolved in pyridine (10 mL) and a solution of DMT-Cl in



pyridine (10 mL) was added dropwise over 15 m. The resulting mixture was stirred at RT for 12 h and MeOH (2 mL) was added to quench the reaction. The mixture was concentrated *in vacuo* and the residue taken up in CH<sub>2</sub>Cl<sub>2</sub> (100 mL) and washed with sat. NaHCO<sub>3</sub>, water and brine. The organic extracts were dried over MgSO<sub>4</sub>, concentrated *in vacuo* and purified over a silica gel column using 50% EtOAc:hexanes as eluant to yield 30 (2.6 g, 3.41 mmol, 69%).

Example 84: 5'-O-DMT-2'-Deoxy-2'-difluoromethylene-6-N-(4-*t*-Butylbenzoyl)-Adenosine 3'-(2-Cyanoethyl *N,N*-diisopropylphosphoramidite) (32)

1-(2'-Deoxy-2'-difluoromethylene-5'-*O*-dimethoxytrityl-β-D-ribofuransyl)-6-*N*-(4-*t*-butylbenzoyl)-adenine 30 (2.6 g, 3.4 mmol) dissolved in dry CH<sub>2</sub>Cl<sub>2</sub> (25 mL) was placed in a round bottom flask under Ar. Diisopropylethylamine (1.2 mL, 6.8 mmol) was added, followed by the dropwise addition of 2-cyanoethyl *N,N*-diisopropylchlorophosphoramidite (1.06 mL, 4.76 mmol). The reaction mixture was stirred 2 h at RT and quenched with ethanol (1 mL). After 10 m the mixture evaporated to a syrup *in vacuo* (40 °C). 32 (2.3 g, 2.4 mmol, 70%) was purified by flash column chromatography over silica gel using 20-50% EtOAc gradient in hexanes, containing 1% triethylamine, as eluant. R<sub>f</sub> 0.52 (CH<sub>2</sub>Cl<sub>2</sub>: MeOH / 15:1).

Example 85: 2'-Deoxy-2'-Methoxycarbonylmethylidene-3',5'-O-(Tetraiso-propyldisiloxane-1,3-diyl)-Uridine (33)

Methyl(triphenylphosphoranylidene)acetate (5.4 g, 16 mmol) was added to a solution of 2'-keto-3',5'-*O*-(tetraisopropyl disiloxane-1,3-diyl)-uridine 14 in CH<sub>2</sub>Cl<sub>2</sub> under argon. The mixture was left to stir at RT for 30 h. CH<sub>2</sub>Cl<sub>2</sub> (100 mL) and water were added (20 mL), and the solution was neutralized with a cooled solution of 2% HCl. The organic layer was washed with H<sub>2</sub>O (20 mL), 5% aq. NaHCO<sub>3</sub> (20 mL), H<sub>2</sub>O to neutrality, and brine (10 mL). After drying (Na<sub>2</sub>SO<sub>4</sub>), the solvent was evaporated *in vacuo* to give crude product, that was chromatographed on a silica gel column. Elution with light petroleum ether:EtOAc / 7:3 afforded pure 2'-deoxy-2'-methoxycarbonylmethylidene-3',5'-*O*-(tetraisopropylidisiloxane-1,3-diyl)-uridine 33 (5.8 g, 10.8 mmol, 67.5%).

Example 86: 2'-Deoxy-2'-Methoxycarbonylmethylidene-Uridine (34)

Et<sub>3</sub>N·3 HF (3 mL) was added to a solution of 2'-deoxy-2'-methoxycarbonylmethylidene-3',5'-O-(tetraisopropylidisiloxane-1,3-diyl)-uridine **33** (5 g, 9.3 mmol) dissolved in CH<sub>2</sub>Cl<sub>2</sub> (20 mL) and Et<sub>3</sub>N (15 mL). The resulting mixture was evaporated *in vacuo* after 1 h and chromatographed on a silica gel column eluting 2'-deoxy-2'-methoxycarbonylmethylidene-uridine **34** (2.4 g, 8 mmol, 86%) with THF:CH<sub>2</sub>Cl<sub>2</sub> / 4:1.

Example 87: 5'-O-DMT-2'-Deoxy-2'-Methoxycarbonylmethylidene-Uridine (35)

2'-Deoxy-2'-methoxycarbonylmethylidene-uridine **34** (1.2 g, 4.02 mmol) was dissolved in pyridine (20 mL). A solution of DMT-Cl (1.5 g, 4.42 mmol) in pyridine (10 mL) was added dropwise over 15 m. The resulting mixture was stirred at RT for 12 h and MeOH (2 mL) was added to quench the reaction. The mixture was concentrated *in vacuo* and the residue taken up in CH<sub>2</sub>Cl<sub>2</sub> (100 mL) and washed with sat. NaHCO<sub>3</sub>, water and brine. The organic extracts were dried over MgSO<sub>4</sub>, concentrated *in vacuo* and purified over a silica gel column using 2-5% MeOH in CH<sub>2</sub>Cl<sub>2</sub> as an eluant to yield 5'-O-DMT-2'-deoxy-2'-methoxycarbonylmethylidene-uridine **35** (2.03 g, 3.46 mmol, 86%).

Example 88: 5'-O-DMT-2'-Deoxy-2'-Methoxycarbonylmethylidene-Uridine 3'-(2-cyanoethyl-N,N-diisopropylphosphoramidite) (36)

1-(2'-Deoxy-2'-2'-methoxycarbonylmethylidene-5'-O-dimethoxytrityl-β-D-ribofuranosyl)-uridine **35** (2.0 g, 3.4 mmol) dissolved in dry CH<sub>2</sub>Cl<sub>2</sub> (10 mL) was placed in a round-bottom flask under Ar. Diisopropylethylamine (1.2 mL, 6.8 mmol) was added, followed by the dropwise addition of 2-cyanoethyl N,N-diisopropylchlorophosphoramidite (0.91 mL, 4.08 mmol). The reaction mixture was stirred 2 h at RT and quenched with ethanol (1 mL). After 10 m the mixture was evaporated to a syrup *in vacuo* (40 °C). 5'-O-DMT-2'-deoxy-2'-methoxycarbonylmethylidene-uridine 3'-(2-cyanoethyl-N,N-diisopropylphosphoramidite) **36** (1.8 g, 2.3 mmol, 67%) was purified by flash column chromatography over silica gel using a 30-60% EtOAc gradient in hexanes, containing 1% triethylamine, as eluant. R<sub>f</sub> 0.44 (CH<sub>2</sub>Cl<sub>2</sub>:MeOH / 9.5:0.5).

Example 89: 2'-Deoxy-2'-Carboxymethylidene-3',5'-O-(Tetraisopropylidisiloxane-1,3-diyl)-Uridine 37

2'-Deoxy-2'-methoxycarbonylmethylidene-3',5'-O-(tetraisopropylidisiloxane-1,3-diyl)-uridine **33** (5.0 g, 10.8 mmol) was dissolved in MeOH (50 mL) and 1 N NaOH solution (50 mL) was added to the stirred solution at RT. The mixture was stirred for 2 h and MeOH removed *in vacuo*. The pH of the aqueous layer was adjusted to 4.5 with 1N HCl solution, extracted with EtOAc (2 x 100 mL), washed with brine, dried over MgSO<sub>4</sub> and concentrated *in vacuo* to yield the crude acid. 2'-Deoxy-2'-carboxymethylidene-3',5'-O-(tetraisopropylidisiloxane-1,3-diyl)-uridine **37** (4.2 g, 7.8 mmol, 73%) was purified on a silica gel column using a gradient of 10-15% MeOH in CH<sub>2</sub>Cl<sub>2</sub>.

The alkyl substituted nucleotides of this invention can be used to form stable oligonucleotides as discussed above for use in enzymatic cleavage or antisense situations. Such oligonucleotides can be formed enzymatically using triphosphate forms by standard procedure. Administration of such oligonucleotides is by standard procedure. See Sullivan *et al.* PCT WO 94/02595.

Oligonucleotides with 3' and/or 5' Dihalophosphonate

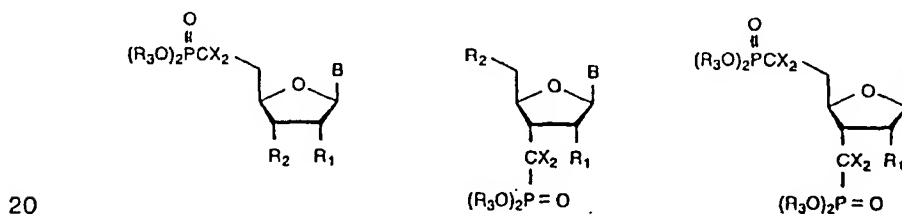
This invention synthesis and uses 3' and/or 5' dihalophosphonate-, e.g., 3' or 5'-CF<sub>2</sub>-phosphonate-, substituted nucleotides that maintain or enhance the catalytic activity and/or nuclease resistance of an enzymatic or antisense molecule.

As the term is used in this application, 5'- and/or 3'-dihalophosphonate nucleotide containing ribozymes, deoxyribozymes (see Usman *et al.*, PCT/US94/11649, incorporated by reference herein), and chimeras of nucleotides, are catalytic nucleic molecules that contain 5'- and/or 3'-dihalophosphonate nucleotide components replacing, but not limited to, double-stranded stems, single-stranded "catalytic core" sequences, single-stranded loops or single-stranded recognition sequences. These molecules are able to cleave (preferably, repeatedly cleave) separate RNA or DNA molecules in a nucleotide base sequence specific manner. Such catalytic nucleic acids can also act to cleave intramolecularly if that is desired. Such enzymatic molecules can be targeted to virtually any RNA or DNA transcript. This invention concerns

nucleic acids formed of standard nucleotides or modified nucleotides, which also contain at least one 5'-dihalophosphonate and/or one 3'-dihalophosphonate group.

The synthesis of 1-O-Ac-2,3-di-O-Bz-D-ribofuranose 5-d-  
 5-dihalomethylphosphonate in three steps from 1-O-methyl-2,3-O-  
 isopropylidene-β-D-ribofuranose 5-deoxy-5-dihalomethylphosphonate is  
 described (e.g., for the difluoro, in Figure 87). Condensation of this suitably  
 derivatized sugar with silylated pyrimidines and purines affords novel  
 nucleoside 5'-deoxy-5'-dihalomethylphosphonates. These intermediates  
 may be incorporated into catalytic or antisense nucleic acids by either  
 chemical (conversion of the nucleoside 5'-deoxy-5'-  
 dihalomethylphosphonates into suitably protected phosphoramidites 12a  
 or solid supports 12b, e.g., Figure 88) or enzymatic means (conversion of  
 the nucleoside 5'-deoxy-5'-dihalomethylphosphonates into their  
 triphosphates, e.g., 14 Figure 89, for T7 transcription).

Thus, in one aspect the invention features 5' and/or 3'-  
 dihalonucleotides and nucleic acids containing such 5' and/or 3'-  
 dihalonucleotides. The general structure of such molecules is shown  
 below.



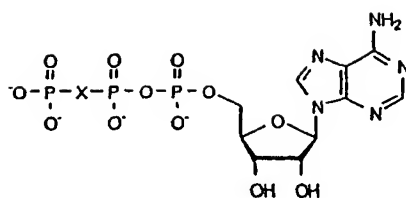
where  $\text{R}_1$  is H, OH, or R, where R is a hydroxyl protecting group, e.g.,  
 acyl, alkylsilyl, or carbonate; each  $\text{R}_2$  is separately H, OH, or R; each  $\text{R}_3$   
 is separately a phosphate protecting group, e.g., methyl, ethyl, cyanoethyl, p-  
 nitrophenyl, or chlorophenyl; each X is separately any halogen; and each B  
 is any nucleotide base.

The invention in particular features nucleic acid molecules having  
 such modified nucleotides and enzymatic activity. In a related aspect the  
 invention features a method for synthesis of such nucleoside 5'-deoxy-5'-  
 dihalo and/or 3'-deoxy-3'-dihalophosphonates by condensing a

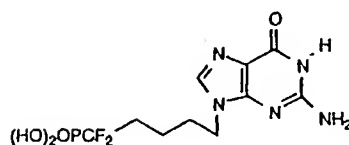
dihalophosphonate-containing sugar with a pyrimidine or a purine under conditions suitable to form a nucleoside 5'-deoxy-5'-dihalophosphonate and/or a 3'-deoxy-3'-dihalophosphonate.

- Phosphonic acids may exhibit important biological properties because of their similarity to phosphates (Engel, *Chem. Rev.* 1977, 77, 349-367). Blackburn and Kent (*J. Chem. Soc., Perkin Trans.* 1986, 913-917) indicate that based on electronic and steric considerations \_-fluoro and \_-difluoromethylphosphonates might mimic phosphate esters better than the corresponding phosphonates. Analogues of pyro- and triphosphates 1, where the bridging oxygen atoms are replaced by a difluoromethylene group, have been employed as substrates in enzymatic processes (Blackburn *et al.*, *Nucleosides & Nucleotides* 1985, 4, 165-167; Blackburn *et al.*, *Chem. Scr.* 1986, 26, 21-24). 9-(5,5-Difluoro-5-phosphonopentyl)guanine (2) has been utilized as a multisubstrate analogue inhibitor of purine nucleoside phosphorylase (Halazy *et al.*, *J. Am. Chem. Soc.* 1991, 113, 315-317). Oligonucleotides containing methylene groups in place of phosphodiester 5'-oxygens are resistant toward nucleases that cleave phosphodiester linkages between phosphorus and the 5'-oxygen (Breaker *et al.*, *Biochemistry* 1993, 32, 9125-9128), but can still form stable complexes with complementary sequences. Heinemann *et al.* (*Nucleic Acids Res.* 1991, 19, 427-433) found that a single 3'-methylenephosphonate linkage had a minor influence on the conformation of a DNA octamer double helix.

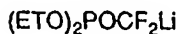
142



1



2



3

- One common synthetic approach to  $\alpha,\alpha$ -difluoro-alkylphosphonates features the displacement of a leaving group from a suitable reactive substrate by diethyl (lithiodifluoromethyl)phosphonate (3) (Obayashi *et al.*, *Tetrahedron Lett.* 1982, 23, 2323-2326). However, our attempts to synthesize nucleoside 5'-deoxy-5'-difluoro-methylphosphonates from 5'-deoxy-5'-iodonucleosides using 3 were unsuccessful, *i.e.* starting compounds were quantitatively recovered. The reaction of nucleoside 5'-aldehydes with 3, according to the procedure of Martin *et al.* (Martin *et al.*, *Tetrahedron Lett.* 1992, 33, 1839-1842), led to a complex mixture of products. Recently, the synthesis of sugar  $\alpha,\alpha$ -difluoroalkylphosphonates from primary sugar triflates using 3 was described (Berkowitz *et al.*, *J. Org. Chem.* 1993, 58, 6174-6176). Unfortunately, our experience is that nucleoside 5'-triflates are too unstable to be used in these syntheses.
- The following are non-limiting examples showing the synthesis of nucleoside 5'-deoxy-5'-difluoromethyl-phosphonates. Those in the art will recognize that equivalent methods can be readily devised based upon

these examples. These examples demonstrate that it is possible to achieve synthesis of 5'-deoxy-5'-difluoro derivatives in good yield and thus guide those in the art to such equivalent methods. The examples also indicate utility of such synthesis to provide useful oligonucleotides as described above.

Those in the art will recognize that useful modified enzymatic nucleic acids can now be designed, much as described by Draper et al., PCT/US94/13129 hereby incorporated by reference herein (including drawings).

10 Example 90: Synthesis of Nucleoside 5'-Deoxy-5'-difluoromethylphosphonates

Referring to Fig. 87, we synthesized a suitable glycosylating agent from the known D-ribose  $\alpha,\alpha$ -difluoromethylphosphonate (4) (Martin et al., *Tetrahedron Lett.* 1992, 33, 1839-1842) which served as a key intermediate for the synthesis of nucleoside 5'-difluoromethylphosphonates.

Methyl 2,3-O-isopropylidene- $\beta$ -D-ribofuranose  $\alpha,\alpha$ -difluoromethylphosphonate (4) was synthesized from the 5-aldehyde according to the procedure of Martin et al. (*Tetrahedron Lett.* 1992, 33, 1839-1842) (Figure 87). Removal of the isopropylidene group was accomplished under mild conditions ( $I_2$ -MeOH, reflux, 18 h (Szarek et al., *Tetrahedron Lett.* 1986, 27, 3827) or Dowex 50 WX8 ( $H^+$ ), MeOH, RT (about 20-25°C), 3 days) in 72% yield. The anomeric mixture thus obtained was benzoylated with benzoyl chloride/pyridine to afford the 2,3-di-O-benzoyl derivative, which was subjected to mild acetolysis conditions (Walczak et al., *Synthesis*, 1993, 790-792) ( $Ac_2O$ , AcOH,  $H_2SO_4$ , EtOAc, 0°C). The desired 1-O-acetyl-2,3-di-O-benzoyl-D-ribofuranose difluoromethylphosphonate (5) was obtained in quantitative yield as an anomeric mixture. These derivatives were used for selective glycosylation of silylated uracil and N<sup>4</sup>-acetylcytosine under Vorbrüggen conditions (Vorbrüggen, *Nucleoside Analogs. Chemistry, Biology and Medical Applications*, NATO ASI Series A, 26, Plenum Press, New York, London, 1980; pp. 35-69. The use of  $F_3CSO_2OSi(CH_3)_3$  as a glycosylation catalyst is precluded because it is expected to lead to the undesired 1-ethyluracil or 9-ethyladenine byproducts: Podyukova, et al., *Tetrahedron*

Letf. 1987, 28, 3623-3626 and references cited therein) ( $\text{SnCl}_4$  as a catalyst, boiling acetonitrile) to yield  $\beta$ -nucleosides (62% 6a, 75% 6b). Glycosylation of silylated N<sup>6</sup>-benzoyladenine under the same conditions yielded a mixture of N-9 isomer 6c and N-7 isomer 7 in 34% and 15% yield, respectively. The above nucleotides were successfully deprotected using trimethylsilylbromide for the cleavage of the ethyl groups, followed by treatment with ammonia-methanol to remove the acyl protecting groups. Nucleoside 5'-deoxy-5'-difluoromethylphosphonates 8 were finally purified on a DEAE Sephadex A-25 ( $\text{HCO}_3^-$ ) column using a 0.01-0.25 M TEAB gradient for elution and obtained as their sodium salts (82% 8a; 87% 8b; 82% 8c).

Selected analytical data:  $^{31}\text{P}$ -NMR ( $^{31}\text{P}$ ) and  $^1\text{H}$ -NMR ( $^1\text{H}$ ) were recorded on a Varian Gemini 400. Chemical shifts in ppm refer to  $\text{H}_3\text{PO}_4$  and TMS, respectively. Solvent was  $\text{CDCl}_3$  unless otherwise noted. 5:  $^1\text{H}$   $\delta$  8.07-7.28 (m, Bz), 6.66 (d,  $J_{1,2}$  4.5,  $\alpha\text{H}1$ ), 6.42 (s,  $\beta\text{H}1$ ), 5.74 (d,  $J_{2,3}$  4.9,  $\beta\text{H}2$ ), 5.67 (dd,  $J_{3,2}$  4.9,  $J_{3,4}$  6.6,  $\beta\text{H}3$ ), 5.63 (dd,  $J_{3,2}$  6.7,  $J_{3,4}$  3.6,  $\alpha\text{H}3$ ), 5.57 (dd,  $J_{2,1}$  4.5,  $J_{2,3}$  6.7,  $\alpha\text{H}2$ ), 4.91 (m, H4), 4.30 (m,  $\text{CH}_2\text{CH}_3$ ), 2.64 (m,  $\text{CH}_2\text{CF}_2$ ), 2.18 (s,  $\beta\text{Ac}$ ), 2.12 (s,  $\alpha\text{Ac}$ ), 1.39 (m,  $\text{CH}_2\text{CH}_3$ ).  $^{31}\text{P}$   $\delta$  7.82 (t,  $J_{\text{P,F}}$  105.2), 7.67 (t,  $J_{\text{P,F}}$  106.5). 6a:  $^1\text{H}$   $\delta$  9.11 (s, 1H, NH), 8.01 (m, 11H, Bz, H6), 5.94 (d,  $J_{1',2'}$  4.1, 1H, H1'), 5.83 (dd,  $J_{5,6}$  8.1, 1H, H5), 5.79 (dd,  $J_{2',1'}$  4.1,  $J_{2',3'}$  6.5, 1H, H2'), 5.71 (dd,  $J_{3',2'}$  6.5,  $J_{3',4'}$  6.4, 1H, H3'), 4.79 (dd,  $J_{4',3'}$  6.4,  $J_{4',\text{F}}$  11.6, 1H, H4'), 4.31 (m, 4H,  $\text{CH}_2\text{CH}_3$ ), 2.75 (tq,  $J_{\text{H,F}}$  19.6, 2H,  $\text{CH}_2\text{CF}_2$ ), 1.40 (m, 6H,  $\text{CH}_2\text{CH}_3$ ).  $^{31}\text{P}$   $\delta$  7.77 (t,  $J_{\text{P,F}}$  104.0). 8c:  $^{31}\text{P}$  (vs DSS) ( $\text{D}_2\text{O}$ )  $\delta$  5.71 (t,  $J_{\text{P,F}}$  87.9).

Compound 7 was deacylated with methanolic ammonia yielding the product that showed  $\lambda_{\text{max}}$  ( $\text{H}_2\text{O}$ ) 271 nm and  $\lambda_{\text{min}}$  233 nm, confirming that the site of glycosylation was N-7.

#### Example 91: Synthesis of Nucleic Acids Containing Modified Nucleotide Containing Cores

The method of synthesis used follows the procedure for normal RNA synthesis as described in Usman *et al.*, *J. Am. Chem. Soc.* 1987, 109, 7845-7854 and in Scaringe *et al.*, *Nucleic Acids Res.* 1990, 18, 5433-5441 and makes use of common nucleic acid protecting and coupling groups, such as dimethoxytrityl at the 5'-end, and phosphoramidites at the 3'-end (Figure 88 and Janda *et al.*, *Science* 1989, 244:437-440.). These



nucleoside 5'-deoxy-5'-difluoromethylphosphonates may be incorporated not only into hammerhead ribozymes, but also into hairpin, hepatitis delta virus, Group 1 or Group 2 introns, or into antisense oligonucleotides. They are, therefore, of general use in any nucleic acid structure.

5    Example 92: Synthesis of Modified Triphosphate

The triphosphate derivatives of the above nucleotides can be formed as shown in Fig. 89, according to known procedures. *Nucleic Acid Chem.*, Leroy B. Townsend, John Wiley & Sons, New York 1991, pp. 337-340; *Nucleotide Analogs*, Karl Heinz Schelt, John Wiley & Sons New York 1980, pp. 211-218.

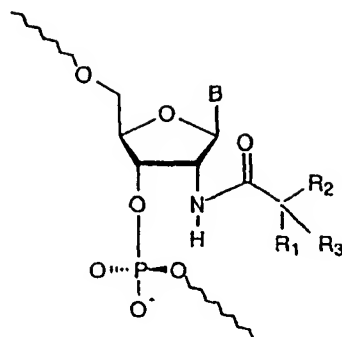
Equivalent synthetic schemes for 3' dihalophosphonates are shown in Figures 90 and 91 using art recognized nomenclature. The conditions can be optimized by standard procedures.

The nucleoside dihalophosphonates described herein are advantageous as modified nucleotides in any nucleic acid structure, e.g., catalytic or antisense, since they are resistant to exo- and endonucleases that normally degrade unmodified nucleic acids *in vivo*. They also do not perturb the normal structure of the nucleic acid in which they are incorporated thereby maintaining any activity associated with that structure. These compounds may also be of use as monomers as antiviral and/or antitumor drugs.

Oligonucleotides with Amido or Peptido Modification

This invention replaces 2'-hydroxyl group of a ribonucleotide moiety with a 2'-amido or 2'-peptido moiety. In other embodiments, the 3' and 5' portions of the sugar of a nucleotide may be substituted, or the phosphate group may be substituted with amido or peptido moieties. Generally, such a nucleotide has the general structure shown in Formula I below:

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FORMULA I

- The base (B) is any one of the standard bases or is a modified nucleotide base known to those in the art, or can be a hydrogen group. In addition, either R<sub>1</sub> or R<sub>2</sub> is H or an alkyl, alkene or alkyne group containing between 2 and 10 carbon atoms, or hydrogen, an amine (primary, secondary or tertiary, e.g., R<sub>3</sub>NR<sub>4</sub> where each R<sub>3</sub> and R<sub>4</sub> independently is hydrogen or an alkyl, alkene or alkyne having between 2 and 10 carbon atoms, or is a residue of an amino acid, i.e., an amide), an alkyl group, or an amino acid (D or L forms) or peptide containing between 2 and 5 amino acids. The zigzag lines represent hydrogen, or a bond to another base or other chemical moiety known in the art. Preferably, one of R<sub>1</sub>, R<sub>2</sub> and R<sub>3</sub> is an H, and the other is an amino acid or peptide.

- Applicant has recognized that RNA can assume a much more complex structural form than DNA because of the presence of the 2'-hydroxyl group in RNA. This group is able to provide additional hydrogen bonding with other hydrogen donors, acceptors and metal ions within the RNA molecule. Applicant now provides molecules which have a modified amine group at the 2' position, such that significantly more complex structures can be formed by the modified oligonucleotide. Such modification with a 2'-amido or peptido group leads to expansion and enrichment of the side-chain hydrogen bonding network. The amide and peptide moieties are responsible for complex structural formation of the oligonucleotide and can form strong complexes with other bases, and interfere with standard base pairing interactions. Such interference will allow the formation of a complex nucleic acid and protein conglomerate.

Oligonucleotides of this invention are significantly more stable than existing oligonucleotides and can potentially form biologically active bioconjugates not previously possible for oligonucleotides. They may also be used for *in vitro* selection of unique aptamers, that is, randomly  
5 generated oligonucleotides which can be folded into an effective ligand for a target protein, nucleic acid or polysaccharide.

Thus, in one aspect, the invention features an oligonucleotide containing the modified base shown in Formula I, above.

In other aspects, the oligonucleotide may include a 3' or 5' nucleotide  
10 having a 3' or 5' located amino acid or aminoacyl group. In all these aspects, as well as the 2'-modified nucleotide, it will be evident that various standard modifications can be made. For example, an "O" may be replaced with an S, the sugar may lack a base (i.e., abasic) and the phosphate moiety may be modified to include other substitutions (see  
15 Sproat, supra).

Example 93: General procedure for the preparation of 2'-aminoacyl-2'-deoxy-2'-aminonucleoside conjugates.

Referring to Fig. 92, to the solution of 2'-deoxy-2'-amino nucleoside (1 mmol) and N-Fmoc L- (or D-) amino acid (1 mmol) in methanol  
20 [dimethylformamide (DMF) and tetrahydrofuran (THF) can also be used], 1-ethoxycarbonyl-2-ethoxy-1,2-dihydroquinoline (EEDQ) [or 1-isobutyloxycarbonyl-2-isobutyloxy-1,2-dihydroquinoline (IIDQ)] (2 mmol) is added and the reaction mixture is stirred at room temperature or up to 50 °C from 3-48 hours. Solvents are removed under reduced pressure and  
25 the residual syrup is chromatographed on the column of silica-gel using 1-10 % methanol in dichloromethane. Fractions containing the product are concentrated yielding a white foam with yields ranging from 85 to 95 %. Structures are confirmed by <sup>1</sup>H NMR spectra of conjugates which show correct chemical shifts for nucleoside and aminoacyl part of the molecule.  
30 Further proofs of the structures are obtained by cleaving the aminoacyl protecting groups under appropriate conditions and assigning <sup>1</sup>H NMR resonances for the fully deprotected conjugate.

Partially protected conjugates described above are converted into their 5'-O-dimethoxytrityl derivatives and into 3'-phosphoramidites using  
35 standard procedures (Oligonucleotide Synthesis: A Practical Approach,

M.J. Gait ed.; IRL Press, Oxford, 1984). Incorporation of these phosphoramidites into RNA was performed using standard protocols (Usman *et al.*, 1987 *supra*).

A general deprotection protocol for oligonucleotides of the present invention is described in Fig. 93.

The scheme shows synthesis of conjugate of 2'-d-2'-aminouridine. This is meant to be a non-limiting example, and those skilled in the art will recognize that, variations to the synthesis protocol can be readily generated to synthesize other nucleotides (e.g., adenosine, cytidine, guanosine) and/or abasic moieties.

Example 94: RNA cleavage by hammerhead ribozymes containing 2'-aminoacyl modifications.

Hammerhead ribozymes targeted to site N (see Fig. 94) are synthesized using solid-phase synthesis, as described above. U4 and U7 positions are modified, individually or in combination, with either 2'-NH-alanine or 2'-NH-lysine.

RNA cleavage assay *in vitro*: Substrate RNA is 5' end-labeled using [ $\gamma$ -<sup>32</sup>P] ATP and T4 polynucleotide kinase (US Biochemicals). Cleavage reactions were carried out under ribozyme "excess" conditions. Trace amount ( $\leq 1$  nM) of 5' end-labeled substrate and 40 nM unlabeled ribozyme are denatured and renatured separately by heating to 90°C for 2 min and snap-cooling on ice for 10 -15 min. The ribozyme and substrate are incubated, separately, at 37°C for 10 min in a buffer containing 50 mM Tris-HCl and 10 mM MgCl<sub>2</sub>. The reaction is initiated by mixing the ribozyme and substrate solutions and incubating at 37°C. Aliquots of 5  $\mu$ l are taken at regular intervals of time and the reaction is quenched by mixing with equal volume of 2X formamide stop mix. The samples are resolved on 20 % denaturing polyacrylamide gels. The results are quantified and percentage of target RNA cleaved is plotted as a function of time.

Referring to Fig. 95, hammerhead ribozymes containing 2'-NH-alanine or 2'-NH-lysine modifications at U4 and U7 positions cleave the target RNA efficiently.

Sequences listed in Figure 94 and the modifications described in Figure 95 are meant to be non-limiting examples. Those skilled in the art will recognize that variants (base-substitutions, deletions, insertions, mutations, chemical modifications) of the ribozyme and RNA containing  
5 other 2'-hydroxyl group modifications, including but not limited to amino acids, peptides and cholesterol, can be readily generated using techniques known in the art, and are within the scope of the present invention.

Example 95: Aminoacylation of 3'-ends of RNA

I. Referring to Fig. 96, 3'-OH group of the nucleotide is converted to succinate as described by Gait, *supra*. This can be linked with amino-alkyl  
10 solid support (for example: CpG). Zig-zag line indicates linkage of 3'OH group with the solid support.

II. Preparation of aminoacyl-derivatized solid support

A) Synthesis of O-Dimethoxytrityl (O-DMT) amino acids

15 Referring to Fig. 97, to a solution of L- (or D-) serine, tyrosine or threonine (2 mmol) in dry pyridine (15 ml) 4,4'-dimethoxytrityl chloride (3 mmol) is added and the reaction mixture is stirred at RT (about 20-25°C) for 16 h. Methanol (10 ml) is then added and the solution evaporated under reduced pressure. The residual syrup was partitioned between 5% aq.  
20 NaHCO<sub>3</sub> and dichloromethane, organic layer was washed with brine, dried (Na<sub>2</sub>SO<sub>4</sub>) and concentrated *in vacuo*. The residue is purified by flash silicagel column chromatography using 2-10% methanol in dichloromethane (containing 0.5 % pyridine). Fractions containing product are combined and concentrated *in vacuo* to yield white foam (75-85 %  
25 yield).

B) Preparation of the solid support and its derivatization with amino acids

Referring to Fig. 97, the modified solid support (has an OH group instead of the standard NH<sub>2</sub> end group) was prepared according to Haralambidis et al., *Tetrahedron Lett.* 1987, 28, 5199, (P denotes  
30 aminopropyl CPG or polystyrene type support). O-DMT or NH-monomethoxytrityl (NH-MMT amino acid was attached to the above solid support using standard procedures for derivatization of the solid support (Gait, 1984, *supra*) creating a base-labile ester bond between amino acids

and the support. This support is suitable for the construction of RNA/DNA chain using suitably protected nucleoside phosphoramidites.

Example 96: Aminoacylation of 5'-ends of RNA

- I. Referring to Fig. 98, 5'-amino-containing sugar moiety was synthesized as described (Mag and Engels, 1989 *Nucleic Acids Res.* 17, 5973). Aminoacylation of the 5'-end of the monomer was achieved as described above and RNA phosphoramidite of the 5'-aminoacylated monomer was prepared as described by Usman *et al.*, 1987 *supra*. The phosphoramidite was then incorporated at the 5'-end of the oligonucleotide using standard solid-phase synthesis protocols described above.
- II. Referring to Fig. 99, aminoacyl group(s) is attached to the phosphate group at the 5'-end of the RNA using standard procedures described above.

VII. Reversing Genetic Mutations

- Modification of existing nucleic acid sequences can be achieved by homologous recombination. In this process a transfected sequence recombines with homologous chromosomal sequences and can replace the endogenous cellular sequence. Boggs, 8 *International J. Cell Cloning* 80, 1990, describes targeted gene modification. It reviews the use of homologous DNA recombination to correct genetic defects. Banga and Boyd, 89 *Proc. Natl. Acad. Sci. U.S.A.* 1735, 1992, describe a specific example of *in vivo* site-directed mutagenesis using a 50 base oligonucleotide. In this methodology a gene or gene segment is essentially replaced by the oligonucleotide used.
- This invention uses a complementary oligonucleotide to position a nucleotide base changing activity at a particular site on a gene (RNA or genomic DNA), such that the nucleotide modifying activity will change (or revert) a mutation to wild-type, or its equivalent. By reversion or change of a mutation, we refer to reversion in a broad sense, such as when a mutation at a second site which leads to functional reversion to a wild type phenotype. Also, due to the degeneracy of the genetic code, a revertant may be achieved by changing any one of the three codon positions. Additionally, creation of a stop codon in a deleterious gene (or transcript) is defined here as reverting a mutant phenotype to wild-type. An example of

this type of reversion is creating a stop codon in a critical HIV proviral gene in a human.

Referring to Figures 100 and 101, broadly there are two approaches to causing a site directed change in order to revert a mutation to wild-type.

5 In one (Fig. 100) the oligonucleotide is used to target RNA specifically. RNA is provided with a complementary (Watson-crick) oligonucleotide sequence to that in the target molecule. In this case the sequence modifying oligonucleotide would (analogously to an antisense oligonucleotide or ribozyme) have to be continuously present to revert the  
10 RNA as it is made by the cell. Such a reversion would be transient and would potentially require continuous addition of more sequence modifying oligonucleotide. The transient nature of this approach is an advantage, in that treatment could be stopped by simply removing the sequence modifying oligonucleotide (as with a traditional drug).

15 A second approach targets DNA (Fig. 101) and has the advantage that changes may be permanently encoded in the target cell's genetic code. Thus, a single course (or several courses) of treatment may lead to permanent reversion of the genetic disease. If inadvertent chromosomal mutations are introduced this may cause cancer, mutate other genes, or  
20 cause genetic changes in the germ-line (in patients of reproductive age). However, if the base changing activity is a specific methylation that may modulate gene expression it would not necessarily lead to germ-line transmission. See Lewin, Genes, 1983 John Wiley & Sons, Inc. NY pp 493-496.

25 Complementary base pairing to single-stranded DNA or RNA is one method of directing an oligonucleotide to a particular site of DNA. This could occur by a strand displacement mechanism or by targeting DNA when it is single-stranded (such as during replication, or transcription). Another method is using triple-strand binding (triplex formation) to double-  
30 stranded DNA, which is an established technique for binding polypyrimidine tracts, and can be extended to recognize all 4 nucleotides. See Povsic, T., Strobel, S., & Dervan, P. (1992). Sequence-specific double-strand alkylation and cleavage of DNA mediated by triple-helix formation. J. Am. Chem. Soc. **114**, 5934-5944 (1992). Knorre, D.G., Valentin, V.V.,  
35 Valentina, F.Z., Lebedev, A.V. & Federova, O.S. *Design and targeted reactions of oligonucleotide derivatives* 1-366 (CRC Press, Novosibirsk,

1993) describe conjugation of reactive groups or enzyme to oligonucleotides and can be used in the methods described herein.

Recently, antisense oligonucleotides have been used to redirect an incorrect splice into order to obtain correct splicing of a splice mutant globin gene *in vitro*. Dominski Z; Kole R (1993) Restoration of correct splicing in thalassemia pre-mRNA by antisense oligonucleotides. Proc Natl Acad Sci U S A 90:8673-7. Analogously, in one preferred embodiment of this invention a complementary oligomer is used to correct an existing mutant RNA, instead of the traditional approach of inhibiting that RNA by antisense.

In either the RNA or DNA mode, after binding to a particular site on the RNA or DNA the oligonucleotide will modify the nucleic acid sequence. This can be accomplished by activating an endogenous enzyme (see Figure 102), by appropriate positioning of an enzyme (or ribozyme) conjugated (or activated by the duplex) to the oligonucleotide, or by appropriate positioning of a chemical mutagen. Specific mutagens, such as nitrous acid which deaminates C to U, are most useful, but others can also be used if inactivation of a harmful RNA is desired.

RNA editing is an naturally occurring event in mammalian cells in which a sequence modifying activity edits a RNA to its proper sequence post-transcriptionally. Higuchi, M., Single, F., Kohler, M., Sommer, B., and Seeburg, P. (1993) RNA Editing of AMPA Receptor Subunit GluR-B: A base-paired intron-exon structure determines position and efficiency Cell 75:1361-1370. The machinery involved in RNA editing can be co-opted by a suitable oligonucleotide in order to promote chemical modification.

The changes in the base created by the methods of this invention cause a change in the nucleotide sequence, either directly, or after DNA repair by normal cellular mechanisms. These changes functionally correct a genetic defect or introduce a stop codon. Thus, the invention is distinct from techniques in which an active chemical group (*e.g.*, an alkylator) is attached to an antisense or triple strand oligonucleotide in order to chemically inactivate the target RNA or DNA.

Thus, this invention creates an alteration to an existing base in a nucleic acid molecule so that the base is read *in vivo* as a different base.



This includes correcting a sequence instead of inactivating a gene but can also include inactivating a deleterious gene.

Thus, in one aspect, the invention features a method for altering in vivo the nucleotide base sequence of a naturally occurring mutant nucleic acid molecule. The method includes contacting the nucleic acid molecule in vivo with an oligonucleotide or peptide nucleic acid or other sequence specific binding molecules able to form a duplex or triplex molecule with the nucleic acid molecule. After formation of the duplex or triplex molecule a base modifying activity chemically or enzymatically alters the targeted base directly, or after nucleic acid repair *in vivo*. This results in the functional alteration of the nucleic acid sequence.

By "alter", as it is used in this context, is meant that one or more chemical moieties in a targeted base, or bases, is altered so that the mutant nucleic acid will be functionally different. Thus, this is distinct from prior methods of correcting defects in DNA, such as homologous recombination, in which an entire segment of the targeted sequence is replaced with a segment of DNA from the transfected nucleic acid. This is also distinct from other methods that use reactive groups to inactivate a RNA or DNA target, in that this method functionally corrects the sequence of the target, instead of merely damaging it, by causing it to be read by a polymerase as a different base from the original base. As noted above, the naturally occurring enzymes in a cell can be utilized to cause the chemical alteration, examples of which are provided below.

By "functionally alter" is meant that the ability of the target nucleic acid to perform its normal function (*i.e.*, transcription or translation control) is changed. For example, an RNA molecule may be altered so that it can cause production of a desired protein, or a DNA molecule can be altered so that upon DNA repair, the DNA sequence is changed.

By "mutant" it is meant a nucleic acid molecule which is altered in some way compared to equivalent molecules present in a normal individual. Such mutants may be well known in the art, and include, molecules present in individuals with known genetic deficiencies, such as muscular dystrophy, or diabetes and the like. It also includes individuals with diseases or conditions characterized by abnormal expression of a gene, such as cancer, thalassemia's and sickle cell anemia, and cystic

fibrosis. It allows modulation of lipid metabolism to reduce artery disease, treatment of integrated AIDS genomes, and AIDS RNA, and Alzheimer's disease. Thus, this invention concerns alteration of a base in a mutant to provide a "wild type" phenotype and/or genotype. For deleterious conditions this involves altering a base to allow expression or prevent expression as is necessary. When treating an infection, such as HIV, it concerns inactivation of a gene in the HIV RNA by mutation of the mutant (*i.e.*, non-human gene) to a wild type (*i.e.*, no production of a non-human protein). Such modification is performed *in trans* rather than *in cis* as in prior methods.

In preferred embodiments, the oligonucleotide is of a length (at least 12 bases, preferably 17 - 22) sufficient to activate dsRNA deaminase *in vivo* to cause conversion of an adenine base to inosine; the oligonucleotide is an enzymatic nucleic acid molecule that is active to chemically modify a base (see below); the nucleic acid molecule is DNA or RNA; the oligonucleotide includes a chemical mutagen, *e.g.*, the mutagen is nitrous acid; and the oligonucleotide causes deamination of 5-methylcytosine to thymidine, cytosine to uracil, or adenine to inosine, or methylation of cytosine to 5-methylcytosine.

In a most preferred embodiment, the invention features correction of a mutation, rather than inactivation of a target by causing a mutation.

Using *in vitro* directed evolution, it is possible to screen for ribozymes with catalytic activities different than RNA cleavage. Bartel, D. and Szostak, J. (1993) Isolation of new ribozymes from a large pool of random sequences. *Science* 261:1411-1418. Using these methods of *in vitro* directed evolution, an enzymatic nucleic acid molecule, or ribozyme that mutates bases, instead of cleaving the phosphodiester backbone can be selected. This is a convenient method of obtaining an enzyme with the appropriate base sequence modifying activities for use in the present invention.

Sequence modifying activities can change one nucleotide to another (or modify a nucleotide so that it will be repaired by the cellular machinery to another nucleotide). Sequence modifying activities could also delete or add one or more nucleotides to a sequence. A specific embodiment of adding sequences is described by Sullenger and Cech, PCT/US94/12976

hereby incorporated by reference herein), in which entire exons with wild-type sequence are spliced into a mutant transcript. The present invention features only the addition of a few bases (1 - 3).

Thus, in another aspect, the invention features ribozymes or enzymatic nucleic acid molecules active to change the chemical structure of an existing base in a separate nucleic acid molecule. Applicant is the first to determine that such molecules would be useful, and to provide a description of how such molecules might be isolated.

Molecules used to achieve *in situ* reversion can be delivered using the existing means employed for delivering antisense molecules and ribozymes, including liposomes and cationic lipid complexes. If the *in situ* reverting molecule is composed only of RNA, then expression vectors can be used in a gene therapy protocol to produce the reverting molecules endogenously, analogously to antisense or ribozymes expression vectors. There are several advantages of using such an expression vector, rather than simply replacing the gene through standard gene therapy. Firstly, this approach would limit the production of the corrected gene to cells that already express that gene. Furthermore, the corrected gene would be properly regulated by its natural transcriptional promoter. Lastly, reversion can be used when the mutant RNA creates a dominant gain of function protein (e.g., in sickle cell anemia), where correction of the mutant RNA is necessary to stop the production of the deleterious mutant protein, and allow production of the corrected protein.

#### Endogenous Mammalian RNA Editing System

It was observed in the mid-1980s that the sequence of certain cellular RNAs were different from the DNA sequence that encodes them. By a process called RNA editing, cellular RNA are post-transcriptionally modified to a) create a translation initiation and termination codons, b) enable tRNA and rRNA to fold into a functional conformation (for a review see Bass, B. L. (1993) In The RNA World, R. Gesteland, R. and Atkins, J. eds. (Cold Spring Harbor, New York; CSH Lab. Press) pp. 383-418). The process of RNA editing includes base modification, deletion and insertion of nucleotides.

Although, the RNA editing process is widespread among lower eukaryotes, very few RNAs (four) have been reported to undergo editing in

mammals (Bass, *supra*). The predominant mode of RNA editing in mammalian system is base modification ( $C \rightarrow U$  and  $A \rightarrow G$ ). The mechanism of RNA editing in the mammalian system is postulated to be that  $C \rightarrow U$  conversion is catalyzed by cytidine deaminase. The mechanism of conversion of  $A \rightarrow G$  has recently been reported for glutamate receptor B subunit (gluR-B) in rat PC12 cells (Higuchi, M. et al. (1993) *Cell* 75, 1361-1370). According to Higuchi gluR-B mRNA precursor attains a structure such that intron 11 and exon 11 can form a stable stem-loop structure. This stem-loop structure is a substrate for a nuclear double strand-specific adenosine deaminase enzyme. The deamination will result in the conversion of  $A \rightarrow I$ . Reverse transcription followed by double strand synthesis will result in the incorporation of G in place of A.

In the present invention, the endogenous deaminase activity or other such activities can be utilized to achieve targeted base modification.

The following are examples of the invention to illustrate different methods by which *in vivo* conversion of a base can be achieved. These are provided only to clarify specific embodiments of the invention and are not limiting to the invention. Those in the art will recognize that equivalent methods can be readily devised within the scope of the claims.

Example 97: Exploiting cellular dsRNA dependent Adenine to Inosine converter:

An endogenous activity in most mammalian cells and *Xenopus* oocytes converts about 50% of adenines to inosines in double stranded RNA. (Bass, B. L., & Weintraub, H. (1988). An unwinding activity that covalently modifies its double-stranded RNA substrate. *Cell*, 55, 1089-1098.). This activity can be used to cause an *in situ* reversion of a mutation at the RNA level. Referring to Figures 102 and 104, for demonstration purposes a stop codon is incorporated into the coding region of dystrophin, which is fused to the reporter gene luciferase. This stop codon can be reverted by targeting an antisense RNA which is long enough to activate the dsRNA deaminase, which converts Adenines to Inosines. The A to I transition will be read by the ribosome as an A to G transition in some cases and will thereby functionally revert the stop codon. While other A's in this region may be converted to I's and read as G, converting an A to I (G) cannot create a stop codon. The A to I transitions

in the region surrounding the target mutation will create some point mutations, however, the function of the dystrophin protein is rarely inactivated by point mutations.

5 The reverted mRNA was then translated in a cell lysate and assayed for luciferase activity. As evidenced by the dramatic increase in luciferase counts in the graph in figure 103, the A to I transition was read by the ribosome as an A to G transition and the stop codon has successfully been reverted with the lysate treated complex. As a control, an irrelevant non-complementary RNA oligonucleotide was added to the  
10 dystrophin/luciferase mRNA. As expected, in this case no translation (luciferase activity) is observed because of the stop codon. As an additional control, the hybrid was not treated with extract, and again no translation (luciferase activity) is observed (Figure 103).

15 While other A's in the targeted region may have been converted to I's and read as G, converting an A to I (G) cannot create a stop codon, so the ribosome will still read through the region. Dystrophin is not generally sensitive to point mutations if the open reading frame is maintained, so a dystrophin protein made from an mRNA reverted by this method should retain full activity.

20 The following detail specifics of the methodology: RNA oligonucleotides were synthesized on a 394 (ABI) synthesizer using phosphoramidite chemistry. The sequence of the synthetic complementary RNA that binds to the mutant dystrophin sequence is as follows (5' to 3'):

CCCGCGGTAGATCTTTCTGGAGGCTTACAGTTTCTACAAACCTCC  
25 CTTCAAA (Seq. ID No. 1)

Referring to Figure 104, fifty-nine base pairs of a human dystrophin mutant sequence containing a stop codon was fused in frame to the luciferase coding region using standard cloning technology, into the *Hind* III and *Not* I sites of pRC-CMV (Invitrogen, San Diego, CA). The AUG of  
30 luciferase was deleted. The sequences of the insert from the *Hind* III site to the start of the luciferase coding region is (5' to 3'):

GCCCCTGAGGAGCGATGGAGGCCTTGAAGGGAGGTTTGTGGAAAA  
CTGTAAGCCTCCAGAAAGATCTACCGCGG (Seq ID No. 2)

This corresponds to base pairs 3649-3708 of normal dystrophin (Entrez ID # 311627) with a *Sac* II site at the 3' end. This plasmid was used as a template for *in vitro* transcription of mRNA using T7 polymerase with the manufacturers protocol (Promega, Madison, WI).

- 5        *Xenopus* nuclear extracts were prepared in 0.5X TGKED buffer (0.5X= 25mM Tris (pH 7.9), 12.5% glycerol, 25 mM KCl, 0.25mM DTT and 0.05mM EDTA), by vortexing nuclei and resuspended in a volume of 0.5X TGKED equal to total cytoplasm volume of the oocytes. Bass, B.L. & Weintraub, H. *Cell* 55, 1089-1098 (1988).
- 10       The target mRNA at 500ng/ul was pre-annealed to 1 micromolar complementary or irrelevant RNA oligonucleotide by heating to 70°C, and allowing it to slowly cool to 37°C over 30 minutes. Fifty nanograms of mRNA pre-annealed to the RNA oligonucleotides was added to 7ul of nuclear extracts containing 1mM ATP, 15mM EDTA, 1600un/ml RNasin
- 15       and 12.5mM Tris pH 8 to a total volume of 12ul. Bass, B.L. & Weintraub, H. *supra*. This mixture, which contains the dsRNA deaminase activity, was incubated for 30 minutes at 25°C. Next, 1.5ul of this mixture was added to a rabbit reticulocyte lysate *in vitro* translation mixture and translated for two hours according to the manufacturers protocol (Life Technologies,
- 20       Gaithersburg, MD), except that an additional 1.3 mM magnesium acetate was added to compensate for the EDTA carried through from the nuclear extract mixture. Luciferase assays were performed on 15ul of extract with the Promega luciferase assay system (Promega, Madison, WI), and luminescence was detected with a 96 well luminometer, and the results are
- 25       displayed in the graph in figure 102.

#### Example 98: Base changing activities

- The chemical synthesis of antisense and triple-strand forming oligomers conjugated to reactive groups is well studied and characterized (Knorre, D.G., Valentin, V.V., Valentina, F.Z., Lebedev, A.V. & Federova,
- 30       O.S. *Design and targeted reactions of oligonucleotide derivatives* 1-366 (CRC Press, Novosibirsk, 1993) and Povsic, T., Strobel, S. & Dervan, P. Sequence-specific double-strand alkylation and cleavage of DNA mediated by triple-helix formation *J. Am. Chem. Soc.* **114**, 5934-5944 (1992). Reactive groups such as alkylators that can modify nucleotide
- 35       bases in targeted RNA or DNA have been conjugated to oligonucleotides.

Additionally enzymes that modify nucleic acids have been conjugated to oligonucleotides. (Knorre, D.G., Valentin, V.V., Valentina, F.Z., Lebedev, A.V. & Federova, O.S. *Design and targeted reactions of oligonucleotide derivatives* 1-366 (CRC Press, Novosibirsk, 1993). In the past these

5 conjugated chemical groups or enzymes have been used to inactivate DNA or RNA that is specifically targeted by antisense or triple-strand interactions. Below is a list of useful base changing activities that could be used to change the sequence of DNA or RNA targeted by antisense or triple strand interactions, in order to achieve *in situ* reversion of mutations,

10 as described herein (see figure 100-104).

1. Deamination of 5-methylcytosine to create thymidine (performed by the enzyme cytidine deaminase (Bass, B.L. in *The RNA World* (Cold Spring Harbor Laboratory Press, Cold Spring Harbor, 1993). Also, nitrous acid or related compounds promote oxidative deamination of

15 C to be read at T (Microbial Genetics, David Freifelder, Jones and Bartlett Publishers, Inc., Boston, 1987, PP.226-230.). Additionally hydroxylamine or related compounds can transform C to be read at T (Microbial Genetics, David Freifelder, Jones and Bartlett Publishers, Inc., Boston, 1987, PP.226-230.)

20 2. Deamination of cytosine to create uracil (performed by the enzyme cytidine deaminase (Bass, B.L. in *The RNA World* (Cold Spring Harbor Laboratory Press, Cold Spring Harbor, 1993) or by chemical groups similar to nitrous acid that promote oxidative deamination (Microbial Genetics, David Freifelder, Jones and Bartlett Publishers, Inc.,

25 Boston, 1987, PP.226-230.)

3. Deamination of Adenine to be read like G (Inosine) (as done by the adenosine deaminase, AMP deaminase or the dsRNA deaminating activity ( Bass, B.L. in *The RNA World* (Cold Spring Harbor Laboratory Press, Cold Spring Harbor, 1993).

30 4. Methylation of cytosine to 5-methylcytosine

5. Transforming thymidine (or uracil) to O<sup>2</sup>-methyl thymidine (or O<sup>2</sup>-methyl uracil), to be read as cytosine by alkynitrosoureas (Xu, and Swann, *Tetrahedron Letters* 35:303-306 (1994)).

6. Transforming guanine to 6-O-methyl (or other alkyls) to be read as adenine (Mehta and Ludlum, *Biochimica et Biophysica Acta*, 521:770-778 (1978) which can be done with the mutagen ethyl methane sulfonate (EMS) Microbial Genetics, David Freifelder, Jones and Bartlett Publishers, Inc., Boston, 1987, PP.226-230.

7. Amination of uracil to cytosine (as performed by the cellular enzyme CTP synthetase (Bass, B.L. in *The RNA World* (Cold Spring Harbor Laboratory Press, Cold Spring Harbor, 1993).

The following are examples of useful chemical modifications that can be utilized in the present invention. There are a few preferred straightforward chemical modifications that can change one base to another base. Appropriate mutagenic chemicals are placed on the targetting oligonucleotide, e.g., nitrous acid, or a suitable protein with such activity. Such chemicals and proteins can be attached by standard procedures. These include molecules which introduce fundamental chemical changes, that would be useful independent of the particular technical approach. See Lewin, *Genes*, 1983 John Wiley & Sons, Inc. NY pp 42-48.

The following matrix shows that the chemical modifications noted can cause transversion reversions (pyrimidine to pyrimidine, or purine to purine) in RNA or DNA. The transversions (pyrimidine to purine, or purine to pyrimidine) are not preferred because these are more difficult chemical transformations. The footnotes refer to the specific desired chemical transformations. The bold footnotes refer to the reaction on the opposite DNA strand. For example, if one desires to change an A to a G, this can be accomplished at the DNA level by using reaction #5 to change a T to a C in the opposing strand. In this example an A/T base pair goes to A/C, then when the DNA is replicated, or mismatch repair occurs this can become G/C, thus the original A has been converted to a G.

### ISR matrix

#### Reverted Base

Mutant base	A	T(U)	C	G
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A	-	Transversion	Transversion	DNA <sup>5,3</sup> /RNA <sup>3</sup>
T(U)	Transversion	-	DNA <sup>5</sup> /RNA <sup>7</sup>	Transversion
C	Transversion	RNA <sup>2</sup> /DNA <sup>6</sup>	-	Transversion
G	DNA <sup>6</sup> /RNA <sup>6</sup>	Transversion	Transversion	-

- 1 Deamination of 5-methylcytosine to create thymidine.
- 2 Deamination of cytosine to create uracil.
- 3 Deamination of Adenine to be read like G (Inosine).
- 5 4 Methylation of cytosine to 5-methylcytosine.
- 5 5 Transforming thymidine (or uracil) to O<sup>2</sup>-methyl thymidine (or O<sup>2</sup>-methyl uracil), to be read as cytosine (Xu, and Swann, Tetrahedron Letters 35:303-306 (1994)).
- 10 6 Transforming guanine to 6-O-methyl (or other alkyls) to be read as adenine (Mehta and Ludlum, Biochimica et Biophysica Acta, 521:770-778 (1978)).
7. 7. Amination of uracil to cytosine. Bass *supra*. fig. 6c.

#### In Vitro Selection Strategy

- Referring to Figure 105, there is provided a schematic describing an
- 15 approach to selecting for a ribozyme with such base changing activity. An RNA is designed that folds back on itself (this is similar to approaches already used to select for RNA ligases, Bartel, D. and Szostak, J. (1993) Isolation of new ribozymes from a large pool of random sequences. Science 261:1411-1418). A degenerate loop opposing the base to be
  - 20 modified provides for diversity. After incubating this library of molecules in a buffer, the RNA is reverse transcribed into DNA (that is, using standard *in vitro* evolution protocol. Tuerk and Gold, 249 Science 505, 1990) , and then the DNA is selected for having a base change. A restriction enzyme cleavage and size selection or its equivalent is used to isolate the fraction
  - 25 of DNAs with the appropriate base change. The cycle could then be repeated many times.

The *in vitro* selection (evolution) strategy is similar to approaches developed by Joyce (Beaudry, A. A. and Joyce, G.F. (1992) Science 257, 635-641; Joyce, G. F. (1992) Scientific American 267, 90-97) and Szostak (Bartel, D. and Szostak, J. (1993) Science 261:1411-1418; Szostak, J. W. (1993) TIBS 17, 89-93). Briefly, a random pool of nucleic acids is synthesized wherein, each member contains two domains: a) one domain consists of a region with defined (known) nucleotide sequence; b) the second domain consists of a region with degenerate (random) sequence. The known nucleotide sequence domain enables: 1) the nucleic acid to bind to its target (the region flanking the mutant nucleotide), 2) complementary DNA (cDNA) synthesis and PCR amplification of molecules selected for their base modifying activity, 3) introduction of restriction endonuclease site for the purpose of cloning. The degenerate domain can be created to be completely random (each of the four nucleotides represented at every position within the random region) or the degeneracy can be partial (Beaudry, A. A. and Joyce, G.F. (1992) Science 257, 635-641). In this invention, the degenerate domain is flanked by regions containing known sequences (see Figure 105), such that the degenerate domain is placed across from the mutant base (the base that is targeted for modification). This random library of nucleic acids is incubated under conditions that ensure folding of the nucleic acids into conformations that facilitate the catalysis of base modification (the reaction protocol may also include certain cofactors like ATP or GTP or an S-adenosyl-methionine (if methylation is desired) in order to make the selection more stringent). Following incubation, nucleic acids are converted into complementary DNA (if the starting pool of nucleic acids is RNA). Nucleic acids with base modification (at the mutant base position) can be separated from rest of the population of nucleic acids by using a variety of methods. For example, a restriction endonuclease cleavage site can either be created or abolished as a result of base modification. If a restriction endonuclease site is created as a result of base modification, then the library can be digested with the restriction endonuclease (RE). The fraction of the population that is cleaved by the RE is the population that has been able to catalyze the base modification reaction (active pool). A new piece of DNA (containing oligonucleotide primer binding sites for PCR and RE sites for cloning) is ligated to the termini of the active pool to facilitate PCR amplification and subsequent cycles (if necessary) of selection. The final pool of nucleic acids with the best base modifying activity is cloned in to a plasmid vector

and transformed into bacterial hosts. Recombinant plasmids can then be isolated from transformed bacteria and the identity of clones can be determined using DNA sequencing techniques.

Base modifying enzymatic nucleic acids (identified via *in vitro* selection) can be used to cause the chemical modification *in vivo*.

In addition, the ribozyme could be evolved to specifically bind a protein having an enzymatic base changing activity.

Such ribozymes can be used to cause the above chemical modifications *in vivo*. The ribozymes or above noted antisense-type molecules can be administered by methods discussed in the above referenced art.

#### VIII. Administration of Nucleic Acids

Applicant has determined that double-stranded nucleic acid lacking a transcription termination signal can be used for continuous expression of the encoded RNA. This is achieved by use of an R-loop, *i.e.*, an RNA molecule non-covalently associated with the double-stranded nucleic acid and which causes localized denaturation ("bubble" formation) within the double stranded nucleic acid (Thomas et al., 1976 Proc. Natl. Acad. Sci. USA 73, 2294). In addition, applicant has determined that the RNA portion of the R-loop can be used to target the whole R-loop complex to a desirable intracellular or cellular site, and aid in cellular uptake of the complex. Further, applicant indicates that expression of enzymatically active RNA or ribozymes can be significantly enhanced by use of such R-loop complexes.

Thus, in one aspect, the invention features a method for introduction of enzymatic nucleic acid into a cell or tissue. A complex of a first nucleic acid encoding the enzymatic nucleic acid and a second nucleic acid molecule is provided. The second nucleic acid molecule has sufficient complementarity with the first nucleic acid to be able to form an R-loop base pair structure under physiological conditions. The R-loop is formed in a region of the first nucleic acid molecule which promotes expression of RNA from the first nucleic acid under physiological conditions. The method further includes contacting the complex with a cell or tissue under

conditions in which the enzymatic nucleic acid is produced within the cell or tissue.

By "complex" is simply meant that the two nucleic acid molecules interact by intermolecular bond formation (such as by hydrogen bonding) between two complementary base-paired sequences. The complex will generally be stable under physiological condition such that it is able to cause initiation of transcription from the first nucleic acid molecule.

The first and second nucleic acid molecules may be formed from any desired nucleotide bases, either those naturally occurring (such as adenine, guanine, thymine and cytosine), or other bases well known in the art, or may have modifications at the sugar or phosphate moieties to allow greater stability or greater complex formation to be achieved. In addition, such molecules may contain non-nucleotides in place of nucleotides. Such modifications are well known in the art, see e.g., Eckstein *et al.*, International Publication No. WO 92/07065; Perrault *et al.*, 1990 Nature 344, 565; Pieken *et al.*, 1991 Science, 253, 314; Usman and Cedergren, 1992 Trends in Biochem. Sci. 17, 334; Usman *et al.*, International Publication No. WO 93/15187; and Rossi *et al.*, International Publication No. WO 91/03162, as well as Sproat, B. *European Patent Application* 92110298.4 which describe various chemical modifications that can be made to the sugar moieties of enzymatic RNA molecules. All these publications are hereby incorporated by reference herein.

By "sufficient complementarity" is meant that sufficient base pairing occurs so that the R-loop base pair structure can be formed under the appropriate conditions to cause transcription of the enzymatic nucleic acid. Those in the art will recognize routine tests by which such sufficient base pairs can be determined. In general, between about 15 - 80 bases is sufficient in this invention.

By "physiological condition" is meant the condition in the cell or tissue to be targeted by the first nucleic acid molecule, although the R-loop complex may be formed under many other conditions. One example is use of a standard physiological saline at 37°C, but it is simply desirable in this invention that the R-loop structure exists to some extent at the site of action so that the expression of the desired nucleic acid will be achieved at that site of action. While it is preferred that the R-loop structure be stable under

those conditions, even a minimal amount of formation of the R-loop structure to cause expression will be sufficient. Those in the art will recognize that measurement of such expression is readily achieved, especially in the absence of any promoter or leader sequence on the first nucleic acid molecule (Daube and von Hippel, 1992 Science 258, 1320).  
5 Such expression can thus only be achieved if an R-loop structure is truly formed with the second nucleic acid. If a promoter or leader sequence is provided, then it is preferred that the R-loop be formed at a site distant from those regions so that transcription is enhanced.

10 In a related aspect, the invention features a method for introduction of ribonucleic acid within a cell or tissue by forming an R-loop base-paired structure (as described above) with the first nucleic acid molecule lacking any promoter region or transcription termination signal such that once expression is initiated it will continue until the first nucleic acid is degraded.

15 In another related aspect, the invention features a method in which the second nucleic acid is provided with a localization factor, such as a protein, *e.g.*, an antibody, transferin, a nuclear localization peptide, or folate, or other such compounds well known in the art, which will aid in targeting the R-loop complex to a desired cell or tissue.

20 In preferred embodiments, the first nucleic acid is a plasmid, *e.g.*, one without a promoter or a transcription termination signal; the second nucleic acid is of length between about 40-200 bases and is formed of ribonucleotides at a majority of positions; and the second nucleic acid is covalently bonded with a ligand such as a nucleic acid, protein, peptide,  
25 lipid, carbohydrate, cellular receptor, nuclear localization factor, or is attached to maleimide or a thiol group: the first nucleic acid is an expression plasmid lacking a promoter able to express a desired gene, *e.g.*, it is a double-stranded molecule formed with a majority of deoxyribonucleic acids; the R-loop complex is a RNA/DNA heteroduplex;  
30 no promoter or leader region is provided in the first nucleic acid; and the R-loop is adapted to prevent nucleosome assembly and is designed to aid recruitment of cellular transcription machinery.

In other preferred embodiments, the first nucleic acid encodes one or more enzymatic nucleic acids, *e.g.*, it is formed with a plurality of

intramolecular and intermolecular cleaving enzymatic nucleic acids to allow release of therapeutic enzymatic nucleic acid *in vivo*.

In a further related aspect, the invention features a complex of the above first nucleic acid molecules and second nucleic acid molecules.

5 R-loop complex

An R-loop complex is designed to provide a non-integrating plasmid so that, when an RNA polymerase binds to the plasmid, transcription is continuous until the plasmid is degraded. This is achieved by hybridizing an RNA molecule, 40 to 200 nucleotides in length, to a DNA expression  
10 plasmid resulting in an R-loop structure (see figure 106). This RNA, when conjugated with a ligand that binds to a cell surface receptor, triggers internalization of the plasmid/RNA-ligand complex. Formation of R-loops in general is described by DeWet, 1987 Methods in Enzymol. 145, 235; Neuwald et al., 1977 J. Virol. 21,1019; and Meyer et al., 1986 J. Ult. Mol.  
15 Str. Res. 96, 187. Thus, those in the art can readily design complexes of this invention following the teachings of the art.

Promoters placed in retroviral genomes have not always behaved as planned in that the additional promoter will serve as a stop signal or reverses the direction of the polymerase. Applicant was told that creation  
20 of an R-loop between the promoter and the reporter gene increased the transfection efficiency. Incubation of an RNA molecule with a double-stranded DNA molecule, containing a region of complementarity with the RNA will result in the formation of a stable RNA-DNA hetroduplex and the DNA strand that has a sequence identical to the RNA will be displaced into  
25 a loop-like structure called the R-loop. This displacement of DNA strand occurs because an RNA-DNA duplex is more stable compared to a DNA-DNA duplex. Applicant was also told that an 80 nt long RNA was used to generate a R-loop structure in a plasmid encoding the  $\beta$ -galactosidase gene. The R-loop was initiated either in the promoter region or in the  
30 leader sequence. Plasmids containing an R-loop structure were microinjected into the cytoplasm of COS cells and the gene expression was assayed. R-loop formation in the promoter region of the plasmid inhibited expression of the gene. RNA that hybridized to the leader sequence between the promoter and the gene, or directly to the first 80  
35 nucleotides of the mRNA increased the expression levels 8-10 fold. The

proposed mechanism is that R-loop formation prevents nucleosome assembly, thus making the DNA more accessible for transcription. Alternatively, the R-loop may resemble a RNA primer promoting either DNA replication or transcription (Daube and von Hippel, 1992, *supra*).

- 5           One of the salient features of this invention is to generate R-loops in expression vectors of choice and introduce them into cells to achieve enhanced expression from the expression vector. The presence of an R-loop may aid in the recruitment of cellular transcription machinery. Once an RNA polymerase binds to the plasmid and initiates transcription, the  
10           process will continue until a termination signal is reached, or the plasmid is degraded.

- This invention will increase the expression of ribozymes inside a cell. The idea is to construct a plasmid with no transcription termination signal, such that a transcript-containing multiple ribozyme units can be  
15           generated. In order to liberate unit length ribozymes, self-processing ribozymes can be cloned downstream of each therapeutic ribozyme (*see figure 107*) as described by Draper *supra*.

#### Ligand Targeting

- Another salient feature of this invention is that the RNA used to  
20           generate R-loop structures can be covalently linked to a ligand (nucleic acid, proteins, peptides, lipids, carbohydrates, *etc.*). Specific ligands can be chosen such that the ligand can bind selectively to a desired cell surface receptor. This ligand-receptor interaction will help internalize a plasmid containing an R-loop. Thus, RNA is used to attach the ligand to the  
25           DNA such that localization of the gene to certain regions of the cell is achieved. One of several methods can be used to attach a ligand to RNA. This includes the incorporation of deoxythymidine containing a 6 carbon spacer having a terminal primary amine into the RNA (*see figure 108*). This amino group can be directly derivatized with the ligand, such as folate (Lee and Low, 1994 *J. Biol. Chem.* 269, 3198-3204). The RNA containing a 6  
30           carbon spacer with a terminal amine group is mixed with folate and the mixture is reacted with activators like 1-(3-Dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride (EDC). This reaction should be carried out in the presence of 1-Hydroxybenzotriazole hydrate (HOBT) to prevent  
35           any undesirable side reactions.

The RNA can also be derivatized with a heterobifunctional crosslinking agent (or linker) like succinimidyl 4-(p-maleimidophenyl)butyrate (SMPB). The SMPB introduces a maleimide into the RNA. This maleimide can then react with a thiol moiety either in a peptide or in a protein. Thiols can also be introduced into proteins or peptides that lack naturally occurring thiols using succinylacetylthioacetate. The amino linker can be attached at the 5' end or 3' end of the RNA. The RNA can also contain a series of nucleotides that do not hybridize to the DNA and extend the linker away from the RNA/DNA complex, thus increasing the accessibility of the ligand for its receptor and not interfering with the hybridization. These techniques can be used to link peptides such as nuclear localization signal (NLS) peptides (Lanford et al., 1984 Cell 37, 801-813; Kalderon et al., 1984 Cell 39, 499-509; Goldfarb et al., 1986 Nature 322, 641-644) and/or proteins like the transferrin (Curiel et al., 1991 Proc. Natl. Acad. Sci. USA 88, 8850-8854; Wagner et al., 1992 Proc. Natl. Acad. Sci. USA 89, 6099-6103; Giulio et al., 1994 Cell. Signal. 6, 83-90) to the ends of R-loop forming RNA in order to facilitate the uptake and localization of the R-loop-DNA complex. To link a protein to the ends of R-loop forming RNA, an intrinsic thiol can be used to react with the maleimide or the thiols can be introduced into the protein itself using either iminothiolate or succinimidyl acetyl thioacetate (SATA; Duncan et al., 1983 Anal. Biochem 132, 68). The SATA requires an additional deprotection step using 0.5 M hydroxylamine.

In addition liposomes can be used to cause an R-loop complex to be delivered to an appropriate intracellular site by techniques well known in the art. For example, pH-sensitive liposomes (Connor and Huang, 1986 Cancer Res. 46, 3431-3435) can be used to facilitate DNA transfection.

Calcium phosphate mediated or electroporation-mediated delivery of the R-loop complex in to desired cells can also be readily accomplished.

### 30 In vitro Selection

*In vitro* selection strategies can be used to select nucleic acids that a) can form stable R-loops b) selectively bind to specific cell surface receptors. These nucleic acids can then be covalently linked to each other. This will help internalize the R-loop-containing plasmid efficiently using receptor-mediated endocytosis. The *in vitro* selection (evolution) strategy is



- similar to approaches developed by Joyce (Beaudry and Joyce, 1992 Science 257, 635-641; Joyce, 1992 Scientific American 267, 90-97) and Szostak (Bartel and Szostak, 1993 Science 261:1411-1418; Szostak, 1993 TIBS 17, 89-93). Briefly, a random pool of nucleic acids is synthesized wherein each member contains two domains: a) one domain consists of a region with defined (known) nucleotide sequence; b) the second domain consists of a region with degenerate (random) sequence. The known nucleotide sequence domain enables: 1) the nucleic acid to bind to its target (a specific region of the double strand DNA), 2) complementary DNA (cDNA) synthesis and PCR amplification of molecules selected for their affinity to form R-loop and/or their ability to bind to a specific receptor, 3) introduction of a restriction endonuclease site for the purpose of cloning. The degenerate domain can be created to be completely random (each of the four nucleotides represented at every position within the random region) or the degeneracy can be partial (Beaudry and Joyce, 1992 Science 257, 635-641). In this invention, the degenerate domain is flanked by regions containing known sequences. This random library of nucleic acids is incubated under conditions that ensure equilibrium binding to either double-stranded DNA or cell surface receptor. Following incubation, nucleic acids are converted into complementary DNA (if the starting pool of nucleic acids is RNA). Nucleic acids with desired characteristics can be separated from the rest of the population of nucleic acids by using a variety of methods (Joyce, 1992 supra). The desired pool of nucleic acids can then be carried through subsequent rounds of selection to enrich the population with the most desired traits. These molecules are then cloned in to appropriate vectors. Recombinant plasmids can then be isolated from transformed bacteria and the identity of clones can be determined using DNA sequencing techniques.
- Other embodiments are within the following claims.

TABLE ICharacteristics of Ribozymes**Group I Introns**

Size: ~200 to >1000 nucleotides.

Requires a U in the target sequence immediately 5' of the cleavage site.

Binds 4-6 nucleotides at 5' side of cleavage site.

Over 75 known members of this class. Found in *Tetrahymena thermophila* rRNA, fungal mitochondria, chloroplasts, phage T4, blue-green algae, and others.

**RNaseP RNA (M1 RNA)**

Size: ~290 to 400 nucleotides.

RNA portion of a ribonucleoprotein enzyme. Cleaves tRNA precursors to form mature tRNA.

Roughly 10 known members of this group all are bacterial in origin.

**Hammerhead Ribozyme**

Size: ~13 to 40 nucleotides.

Requires the target sequence UH immediately 5' of the cleavage site.

Binds a variable number nucleotides on both sides of the cleavage site.

14 known members of this class. Found in a number of plant pathogens (virusoids) that use RNA as the infectious agent (Figures 1 and 2)

**Hairpin Ribozyme**

Size: ~50 nucleotides.

Requires the target sequence GUC immediately 3' of the cleavage site.

Binds 4-6 nucleotides at 5' side of the cleavage site and a variable number to the 3' side of the cleavage site.

Only 3 known member of this class. Found in three plant pathogen (satellite RNAs of the tobacco ringspot virus, arabis mosaic virus and chicory yellow mottle virus) which uses RNA as the infectious agent (Figure 3).

**Hepatitis Delta Virus (HDV) Ribozyme**

Size: 50 - 60 nucleotides (at present).

Cleavage of target RNAs recently demonstrated.

Sequence requirements not fully determined.

Binding sites and structural requirements not fully determined, although no sequences 5' of cleavage site are required.

Only 1 known member of this class. Found in human HDV (Figure 4).

***Neurospora* VS RNA Ribozyme**

Size: ~144 nucleotides (at present)

Cleavage of target RNAs recently demonstrated.  
Sequence requirements not fully determined.  
Binding sites and structural requirements not fully determined. Only 1  
known member of this class. Found in *Neurospora* VS RNA (Figure 5).

Table 2  
Human ICAM HH Target sequence

nt. Position	Target Sequences	nt. Position	Target Sequences
11	CCCCAGU C GACGCTG	386	ACCGUGU A CUGGACTU
23	CUGAGCU C CUCGCTU	394	CUGGACTU C CAGAACG
26	AGCUCCU C UGCUACU	420	CACCCCU C CCUCUCU
31	CUCUGCU A CUCAGAG	425	CUCCCCU C UUGGCAG
34	UGCUACU C AGAGUUG	427	CCCCUCU U GGCAGCC
40	UCAGAGU U GCAACCU	450	AGAACCU U ACCCUAC
48	GCAACCU C AGCCUCG	451	GAAACCU A CCUACG
54	UCAGCCU C GCUAUGG	456	UUAACCU A CGCUGCC
58	CCUCCCU A UGGCUCU	495	CCAACCU C ACCGUGG
64	UAUGGCU C CCAGCAG	510	UGCUGCU C CGUGGGG
96	CCGACCU C CUGGUCC	564	CUGAGGU C ACCACCA
102	UCCUGGU C CUCGUCG	592	GAGAGAU C ACCAUGG
108	UCCUGCU C GGGGCUU	607	AGCCAAU U UCUUGUG
115	CGGGGCU C UGUUCCC	608	GCCAAAU U CUGGUGC
119	GCUCUGU U CCCAGGA	609	CCAAUUU C UCGUGCC
120	CUCUGUU C CCAGGAC	611	AAUUUUU C GUGCCGC
146	CAGACAU C UGUGUCC	656	GAGCUGU U UGAGAAC
152	UCUGUGU C CCCCUCA	657	AGCUGUU U GAGAACA
158	UCCCCCU C AAAAGUC	668	AACACCU C GGGCCCC
165	CAAAAGU C AUCCUGC	677	GCCCCCU A CCAGCUC
168	AAGUCAU C CUGCCCC	684	ACCAGCU C CAGACCU
185	GGAGGCU C CGUGCUG	692	CAGACCU U UGUCCUG
209	AGCACCU C CUGUGAC	693	AGACCUU U GUCUUGC
227	CCCAAGU U GUUGGGC	696	CCUUUGU C CUGCCAG
230	AAGUUGU U GGGCAUA	709	AGCGACU C CCCCACA
237	UGGGCAU A GAGACCC	720	CACAACU U GUCAGCC
248	ACCCCGU U GCCUAAA	723	AACUUGU C AGCCCCC
253	GUUGCCU A AAAAGGA	735	CCCGGGU C CUAAGG
263	AAGGAGU U GCUCUUG	738	GGGUCCU A GAGGUGG
267	AGUUGCU C CUGCCUG	765	CCGUGGU C UGUUCCC
293	AAGGUGU A UGAACUG	769	GGUCUGU U CCUGGGA
319	AGAAGAU A GCCAACCC	770	GUCUGUU C CCUGGAC
335	AUGUGCU A UUCAAAC	785	GGGCGGU U CCCAGUC
337	GUGCUAU U CAAACUG	786	GGCUGUU C CCAGUCU
338	UGCUAUU C AAACUGC	792	UCCCAGU C UCGAGG
359	GGGCAGU C AACAGCU	794	CCAGUCU C GGAGGCC
367	AACAGCU A AAACCUU	807	CCCAGGU C CACCUGG
374	AAAACCU U CCUCACC	833	CAGAGGU U GAACCCC
375	AAACCUU C CUCACCG	846	CCACAGU C ACCUAUG
378	CCUUCU C ACCGUGU	851	GUCACCU A UGGCAAC

863	AACGACU C CUUCUUG	1408	UUGAGAU C UUGAGGG
866	GACUCCU U CUUGGCC	1410	GAGAUCCU U GAGGGCA
867	ACTUCCU C UUGGCCA	1421	GGCAACU A CCUCUGU
869	UCCUUCU C GGCCAAG	1425	CCUACCU C UGUCCGG
881	AAGGCCU C AGUCAGU	1429	CCUCUGU C GGGCCAG
885	CCUCAGU C AGUGUGA	1444	GAGCACU C AAGGGGA
933	GUGCAGU A AUACUGG	1455	GGGAGGU C ACCCGCG
936	CAGUAAU A CUUGGGA	1482	AUGUGCU C UCCCCC
978	UGACCAU C UACAGCU	1484	GUGUCU C CCCCCG
980	ACCAUCU A CAGCUUU	1493	CCCCGGU A UGAGAUU
986	UACAGCU U UCCGGCG	1500	AUGAGAU U GUCAUCA
987	ACAGCUU U CCGGGCG	1503	AGAUUGU C AUCAUCA
988	CAGCUUU C CCGGGCG	1506	UUGUCAU C AUCAUCG
1005	ACGUGAU U CUGACGA	1509	UCAUCAU C ACUGUGG
1006	CGUGAUU C UGAGGAA	1518	CUUGUGU A GCAGCCG
1023	CAGAGGU C UCAGAAG	1530	CCGCAU C AUAAUGG
1025	GAGGUCU C AGAAGGG	1533	CAGUCAU A AUGGGCA
1066	CCACCCU A GAGCCAA	1551	CAGGCCU C AGCAAGU
1092	AUGGGGU U CCAGCCC	1559	AGCAAGU A CCUCUAU
1093	UGGGGUU C CAGCCCA	1563	CGUACCU C UAUAAAC
1125	CCCAGCU C CUGCUGA	1565	UACCUU A UAACCGC
1163	CGCAGCU U CUCCUGC	1567	CCUCUAU A ACGGCA
1164	GCAGCUU C UCCUGCU	1584	GGAAGAU C AAGAAAU
1166	AGCUUCU C CUGUCU	1592	AAGAAU A CAGACUA
1172	UCCUGCU C UGCAACC	1599	ACAGACU A CAACAGG
1200	GCCAGCU U AUACACA	1651	CACGCCU C CCUGAAC
1201	CCAGCUU A UACACAA	1661	UGAACCU A UCCCGGG
1203	AGCUUAD A CACAAGA	1663	AACCUU C CCGGGAC
1227	GGGAGCU U CGUGUCC	1678	AGGGCCU C UUCUUG
1228	GGAGCUU C GUGUCCU	1680	GGUCCU U CCUGGCG
1233	UUCGUGU C CUGUAUG	1681	GCCUCU C CUUGGCC
1238	GUCCUGU A UGGCCCC	1684	UCUUCU C GGCUUUC
1264	GAGGGAU U GUCCGGG	1690	UCCGCCU U CCCAUU
1267	GAUUGU C CGGAAA	1691	CGGCCU C CCAUUAU
1294	AGAAAAU U CCCAGCA	1696	UUCUCAU A UUGGUGG
1295	GAAAAU C CCAGCAG	1698	CCAUUAU U GGUGGCA
1306	GCAGACU C CAAGUGG	1737	AAGACAU A UGCCADG
1321	CCAGGCU U GGGGGAA	1750	UGCAGCU A CACCUAC
1334	AACCCAU U GCGGAG	1756	UACACCU A CCGGCC
1344	CCGAGCU C AAGUGUC	1787	AGGGCAU U GUCCUCA
1351	CAAGUGU C UAAAGGA	1790	GCAUUGU C CUCAGUC
1353	AGUGUCU A AAGGAUG	1793	UUGUCCU C AGUCAGA
1366	UGGCACU U UCCACU	1797	CCUCAGU C AGAUACA
1367	GGCACUU U CCCACUG	1802	GUCAUUA A CAACAGC
1368	GCACUUU C CCACUGC	1812	ACAGCAU U UGGGGCC
1380	UGCCCAU C GGGGAUU	1813	CAGCAU U GGGGCCA
1388	GGGGAU C AGUGACU	1825	CCAUGGU A CUGGCAC
1398	UGACUGU C ACUCGAG	1837	CACACCU A AAACACU
1402	UGUCACU C GAGAUUC	1845	AAACACU A GGCCAGC

1856	CACGCAU C UGADCUG	2189	UAUUUAU U GAGGGUC
1861	AUCUGAU C UGUAGUC	2196	UGAGUGU C UUUUAUG
1865	GAUCUGU A GUCACAU	2198	AGUGUCU U UUAUGUA
1868	CUGUAGU C ACADGAC	2199	GUGUCUU U UADGUAG
1877	CAUGACTU A AGCCAAG	2200	UGUCUUU U ADGUAGG
1901	CAAGACU C AAGACAU	2201	GUCUUUU A UGUAGGC
1912	ACAUGAU U GADGGAU	2205	UUUAUGU A GGCTAAA
1922	UGGAUGU U AAAGUCU	2210	GUAGGCU A AAUGAAC
1923	GGAUUUU A AAGGCUA	2220	UGAACAU A GGUCUCU
1928	UUAAAGU C UAGCCUG	2224	CAUAGGU C UCGGGCC
1930	AAAGUCU A GCTUGAU	2226	UAGGUCU C UGGCTUC
1964	GAGACAU A GCOCCAC	2233	CGGGCCU C ACCGAGC
1983	AGGACAU A CACUGG	2242	CGGAGCU C CCAGUCC
1996	GGGAAAU C UGAAAC	2248	UCCAGU C CAUGUCA
2005	UGAAACU U GCGCCU	2254	UCCAUU C ACAUACA
2013	GCUGCCU A UUGGGUA	2259	GUACAUU U CAGGUC
2015	UGCCUAU U GGGUADG	2260	UCACAUU C AAGGUCA
2020	AUUGGGU A UGCGAG	2266	UCAAGGU C ACCAGGU
2039	ACAGACU U ACAGAAG	2274	ACCAGGU A CAGUUGU
2040	CAGACUU A CAGAAGA	2279	GUACAGU U GUACAGG
2057	UGGCCCC C CAUAGAC	2282	CAGUUGU A CAGGUUG
2061	CCUCCAU A GACAUUGU	2288	UACAGGU U GUACACU
2071	CADUGGU A GCACCAA	2291	AGGUUGU A CACUGCA
2076	GUAGCAU C AAAACA	2321	AAAAGAU C AAADGGG
2097	CCACACU U CCGGACG	2338	UGGGACU U CUCAUUG
2098	CACACUU C CUGACGG	2339	GGGACUU C UCADUGG
2115	GCCAGCU U GGGCACU	2341	GACUUCU C ADUGGCC
2128	CUUGUCU C UACUGAC	2344	UUCUACU U GGCACAC
2130	GCUGUCU A CUGACCC	2358	CCUGCCU U UCCCCAG
2145	CAACCCU U GADGAUA	2359	CUUGCCU U CCCCAGA
2152	UGADGAU A UGUUUUU	2360	UGCCUUU C CCCAGAA
2156	GAUUAUGU A UUUUAUC	2376	GAGUGAU U UUUUAU
2158	UAUGUAU U UAUUCAU	2377	AGUGAUU U UUCUAUC
2159	AUGUAUU U AUUCAUU	2378	GUGAUUU U UCUAUCG
2160	UGUAUUU A UUCAUUU	2379	UGAUUUU U CUADCGG
2162	UAUUUAU U CAUUUGU	2380	GAUUUUU C UADCGGC
2163	AUUUAUU C AUUUGUU	2382	UUUUUCU A UCGGCAC
2166	UAUUCAU U UGUUAUU	2384	UUUCUAU C GGCACAA
2167	AUUCAUU U GUUAUUU	2399	AAGCACU A UADGGAC
2170	CAUUUGU U AUUUUAC	2401	GCACUAU A UGGACUG
2171	AUUUGUU A UUUUACC	2411	GACUGGU A ADGGUUC
2173	UUGUUUU U UUAACCAG	2417	UUAUGGU U CACAGGU
2174	UGUUUUU U UAACCAGC	2418	AAUGGUU C ACAGGUU
2175	GUUAUUU U ACCAGCU	2425	CACAGGU U CAGAGAU
2176	UUUAUUU A CCAGCUA	2426	ACAGGUU C AGAGAUU
2183	ACCAGCU A UUUUAUG	2433	CAGAGAU U ACCCAGU
2185	CAGCUAU U UAUUGAG	2434	AGAGAUU A CCCAGUG
2186	AGCUAUU U AUUGAGU	2448	GAGGCCU U AUUCUUC
2187	GCUAUUU A UUGAGUG	2449	AGGCCUU A UUCUUC

2451	GCCUUAU	U	CCUCCCU	2750	UAUGUGU	A	GACAAGC
2452	CCUUAUU	C	CUCCCUU	2759	ACAAGCU	C	UCGCUCU
2455	UAUUCUU	C	CCUCCCC	2761	AAGCUUU	C	GCUCUGU
2459	CCUCCCU	U	CCCCCAA	2765	UCUUGCU	C	UGUCACC
2460	CUCCCUU	C	CCCCCAA	2769	GCUCUGU	C	ACCCAGG
2479	GACACCU	U	UGUUAGC	2797	GUGCAAU	C	AUGGUUC
2480	ACACCUU	U	GUUAGCC	2803	UCAUGGU	U	CACUGCA
2483	CCUUGGU	U	AGCCACC	2804	CAUGGUU	C	ACUGCAG
2484	CUUUGGU	A	GCCACCU	2813	CUGCAGU	C	UUGACCU
2492	GCCACCU	C	CCCACCC	2815	GCAGUCU	U	GACCUUU
2504	CCCACAU	A	CAUUCUU	2821	UUGACCU	U	UUGGGCU
2508	CAUACAU	U	UCUGCCA	2822	UGACCUU	U	UGGGCUC
2509	AUAACAU	U	CUGCCAG	2823	GACCUUU	U	GGGCUCA
2510	UACAUUU	C	UGCCAGU	2829	UUGGGCU	C	AAGUGAU
2520	CCAGUGU	U	CACAATG	2837	AAGUGAU	C	CUCCAC
2521	CAGUGUU	C	ACAAUGA	2840	UGAUCCU	C	CCACCCU
2533	UGACACTU	C	AGCGGUC	2847	CCCACCU	C	AGCCUCC
2540	CAGCGGU	C	AUGGCTG	2853	UCAGCCU	C	CUGAGUA
2545	GUCAUGU	C	UGGACAU	2860	CCUGAGU	A	GCUGGGA
2568	AGGGAUU	A	UGCCCAA	2872	GGACCAU	A	GGCUCAC
2579	CCAAGCU	A	UGCCUUG	2877	AUAGGCU	C	ACAACAC
2585	UAGGCUU	U	GUCCUCU	2899	GGCAAAU	U	UGAUUUU
2588	GCCUUGU	C	CUUUGU	2900	GCAAAUU	U	GAAUUUU
2591	UUGUCCU	C	UUGUCCU	2904	AUUUGAU	U	UUUUUUU
2593	GUCCUCU	U	GUCCUGU	2905	UUUGAUU	U	UUUUUUU
2596	CUUUGGU	C	CUUUGGU	2906	UUGAUUU	U	UUUUUUU
2601	GUCCUGU	U	UGCAUUU	2907	UGAUUUU	U	UUUUUUU
2602	UCCUGGU	U	GCAUUCU	2908	GAUUUUU	U	UUUUUUU
2607	UUUGCAU	U	UACUUGG	2909	AUUUUUU	U	UUUUUUU
2608	UUGCAUU	U	CACUGGG	2910	UUUUUUU	U	UUUUUUU
2609	UGCAUUU	C	ACUGGGA	2911	UUUUUUU	U	UUUUUUU
2620	GGGAGCU	U	GCACTAU	2912	UUUUUUU	U	UUUUUUC
2626	UUGCACTU	A	UUGCAGC	2913	UUUUUUU	U	UUUUUCA
2628	GCACUUA	U	GCAGCUC	2914	UUUUUUU	U	UUUUUCAG
2635	UGCAGCU	C	CAGUUUC	2915	UUUUUUU	U	UUUUCAGA
2640	CUCCAGU	U	UCCUGCA	2916	UUUUUUU	U	UUUCAGAG
2641	UCCAGUU	U	CCUGCAG	2917	UUUUUUU	U	UCAGAGA
2642	CCAGUUU	C	CUGCAGU	2918	UUUUUUU	U	CAGAGAC
2653	CAGUGAU	C	AGGGUCC	2919	UUUUUUU	C	AGAGACG
2659	UCAGGGU	C	CCGCAAG	2931	ACGGGGU	C	UCGCAAC
2689	CCAAGGU	A	UUGGAGG	2933	GGGGGCU	C	GCAACAU
2691	AAGGUUA	U	GGAGGAC	2941	GCAACAU	U	GCCCAGA
2700	GAGGACTU	C	CCUCCCA	2951	CCAGACU	U	CCUUUGU
2704	ACUCCCU	C	CCAGCUU	2952	CAGACTU	C	CUUUGUG
2711	CCCAGCU	U	UGGAAGG	2955	ACUCCCU	U	UGUGUUA
2712	CCAGCUU	U	GGAAGGG	2956	CUUCCCU	U	GUGUUG
2721	GAAGGGU	C	AUCCGCG	2961	UUUGUGU	U	AGUUAAU
2724	GGGUCAU	C	CGCGUGU	2962	UUGUGUU	A	GUUAAUA
2744	UGUGUGU	A	UGUGUAG	2965	UGUUGAU	U	AUUAAAG

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2966	GUGAGUU A	ADAAAGC
2969	AGUUAUU A	AAGCGUU
2975	UAAAGCU U	UCUCAAC
2976	AAAGCUU U	CUCAACU
2977	AAGCUUU C	UCAACUG
2979	GCUUUUU C	AACUGGC



Table 3

Mouse ICAM HH Target Sequence

nt. Position	Target Sequence	nt. Position	Target Sequence
11	CCUgGU C acGGuUG	367	AAugGCU u cAAOCcg
23	CaGuGgU u CUUGGCU	374	gAAgOCU U CUUgcCC
26	uGgUuCU C UGUUcCU	375	AAgCCU C CUgcCCc
31	CUUGGCU c CUUcaca	378	CUacCaU C ACCGUGU
34	UuCUcaU a AGgGUcG	386	ACCGUGU A uUcGuuU
40	gCacAcU U GuAgCCU	394	CcGGACT u ucGauCu
48	aggAOCU C AGGUGG	420	CACaCuU C CCCcCcg
54	UggGCCU C GuG AUGG	425	CaOCCU C ccaGCAG
58	CaUgcCU u UaGUCC	427	CagUCU c aGCAGug
64	cAocccU C CCAGCAG	450	AGgAOCU c ACCCUgc
96	CucugCU C CUGGcCC	451	GAAaCcU u uCCUuuG
102	UgCcaGU a CUGGUGG	456	UUAOCU c aGCcaCu
108	cUCUGCU C cuGGCCc	495	CUAcCaU C ACCGUGu
115	uGGuuCU C UGUUCCu	510	UGUGGCU C CGUGGGG
119	GgaaUGU c aCCAGGA	564	CUcAGGU a uCcAuCc
120	CUUGGCU C CugGccC	592	GAaAGAU C ACAugGG
146	CAGuCgU C cGcuUCC	607	AGCCAAU U UCUCaUG
152	UCUGUGU C agCCaCu	608	GCCAAU U CUcaUGC
158	UCCuGuU u AAAAacC	609	CCAAUUC U CcaUGCC
165	CAgAAGU u gUuuUGC	611	AAUUCU C aUGCCGC
168	AAGcCuU C CUGOCCC	656	aAGCUGU U UGAGcug
185	GGUGGgU C CGUGCaG	657	AGCUGUU U GAGcugA
209	gcCAcuU C CUUGgC	668	cgagCCU a GGCCaCC
227	CagAAGU U GUUuUGC	677	GaCCuCU A CCAGCcu
230	AAGUUGU U uuGcucc	684	uuCAGCU C CgGuCCU
237	UGUGCuU u GAGaZCu	692	CgGACuU U cGauCUu
248	AaCCCaU c uCCUAAA	693	AGgaCcU c acCCUGC
253	ccUGCCU A AggAaGA	696	CCUgUuU C CUGCCuc
263	AgGGuuU c uCUaCUG	709	gGCGgCU C CaCCuCA
267	AGggGCU C CUGCCUa	720	uACAACT U uUCAGCu
293	AAGcUGU u UGAgCUG	723	AACTUuU C AGCuCCg
319	AGgAGAU A cugAgCC	735	zCCCaGU C CUgGAGa
335	cUGUGCU u UgggAAC	738	uGGgCCU c GuGaUGG
337	GUcCaAU U CAcACUG	765	CaGUcGU c cGcUuCC
338	aGCUgUu u gAgCUGa	769	GGcCUGU U uCCUGcc
359	GuGCAGU C guCcGCU	770	uUuUGcU C CCUGGAa
785	GGcCUGU U uCCUGcC	1353	AGUGggU c gAaGgUG
786	GcCUGUu u CCUGcCU	1366	UaaCAgU c UaCaACU
792	UggagGU C UCGGAaG	1367	zGCACcU c CCCACcu
794	CugGgCU u GGAaCu	1368	GuACUGU a CCACUcu
807	CuGgGaU z uACCUGG	1380	UGCCCAU c GGGGugg
833	CAzAGcU c GAcacCC	1388	GGaGAcU C AGUGgCU
846	CCcugGU C ACCguUG	1398	UGgCUGU C ACagaAc
851	GagACCU c UaocAgC	1402	UGUgcUu u GAGaZCU

863	AgCeACTU u CeUCUgG	1408	gCGAGAU C ggGgaGG
866	GAagCCU U CcuGcCC	1410	GAGgUCU c GgaaGgg
867	AuUCgUU u cCGGagA	1421	ccCAACCU A CuUuUGU
869	UCuUcCU C auGCAAG	1425	aCUgCCU u gGUaGaG
881	AuGGCUU C AacCcGU	1429	uCUCTaU u GccCCuG
885	CCUugGU a gagGUGA	1444	GAaggCU C AgGaGGA
933	cUauAaU c ADuCCGG	1455	GGaAuGU C ACCaGga
936	uAaUcAU u CGGuGc	1482	AgUUGuU u UgCuCCC
978	UAACagU C UACaZCU	1484	cUGuUCU u CCuCauG
980	ACagUCU A CAaCUUU	1493	CuguGcU u UGAGAac
986	UACAACTU U UuCaGCU	1500	ADGAaAU c aUggUCc
987	ACAaCUU U uCaGCUc	1503	gGAcUaU a ADCAUuc
988	CAaCUUU u CaGCUCC	1506	UJaUgruU u AUaACcG
1005	ACcaGAU c CGGgaGA	1509	cuAcCAU C ACCGUGU
1006	uGaGAgU C UGggGAA	1518	ucaUGGU c cCAGgCG
1023	ugGAGGU C UCgGAAG	1530	CuauAaU C AUucUGG
1025	GAGGUUU C gGAAGGG	1533	ugGUCAU u gUGGGCc
1066	CCAaCUU c aAaauAA	1551	CAuGCCU u AGCagcU
1092	AcuUGaU c uCAgGCC	1559	AGCAcCU c CCcaccU
1093	UGGaccU u CAGCCaA	1563	CuUAugU u UAUAAcc
1125	CCCAaCU C uUcuUGA	1565	UAugUuU A UAACCGC
1163	CGaAGCU U CUuuUGC	1567	ugUuUAU A ACCGCCA
1164	GaAGCUU C UuuUGCU	1584	GaAAGAU C AgGauAU
1166	AGCUUCU u uUGCUUU	1592	AgGAuAU A CAaguUA
1172	UCCUGuU u aaaAACC	1599	ACAaguU A CAgaAGG
1200	cuCuGCU c cUcCACA	1651	CcCaCCU C CCTGAgC
1201	gCuGCUU u UgaACAg	1661	gaAAACCU u UCCuuuG
1203	AcuUuUu u CACcAGu	1663	AACCUuU C UuuuGAA
1227	GUuAcaU a CGUGUGC	1678	AGGaCCU C agCCUgG
1228	GaAGCUU C uUuUgCU	1680	aGCCaCU U CCUCuGg
1233	UUCGUuU C CgGagaG	1681	GCCaCUU C CUcuGgC
1238	GUgCUGU A UGUcCCu	1684	aCUUCUU C uGgCUgu
1264	GAAggGU c GUgCaaG	1690	cCGGaCU U uCgAUcU
1267	uGAgaGU C uGGGgAA	1691	CGGaCUU u CgAUcUU
1294	AGgAgAU a CugAGCc	1696	UgCCCAU c ggGGUGG
1295	GAggggU C uCAGCAG	1698	CggAUUAU a ccUGGag
1306	GCAGACU C ugAaaUG	1737	gAGAcCU c UaCCAgc
1321	gaAGGCU c aGGAgGA	1750	gGCgGCU c CAOCUca
1334	AACCCAU c uCCuaAa	1756	gAagCCU u CCuGCC
1344	auGAGCU C gAGaGUg	1787	gaGaCAU U GUCCcCA
1351	ugAaUGU a UAAGuuA	1790	GCauUGU u CUuaau
1793	UgGUCCU C gGcugGA	2173	UUagagU U UUAOCAG
1797	CacCAGU C ACAUAaA	2174	UagagUU U UAACCAGC
1802	acCAGAU c CuggAGa	2175	agagUUU U ACCAGCU
1812	ACuGgAU c UcaGGCC	2176	gagUUUU A CCAGCUA
1813	CAGCAUU U acccuCA	2183	ACCAGCU A UUUUAUG
1825	CCAacGU A CCTcugC	2185	CAGCUAU U UAUGAG
1837	CAugCCU u uAGCuCc	2186	AGCUAUU U AUUGAGU
1845	cgAgcCU A GGCCACc	2187	GCUAUUU A UUGAGUA

1856	CggaCuU u cGADCUu	2189	UAUUUAU U GAGUacC
1861	AcaUGAU a UccAGUa	2196	caAcUcU u cUUGADG
1865	cAcuUGU A GcCuCAg	2198	gcaGcCU c UUAUGUu
1868	CaccAGU C ACADaAa	2199	GccUcUu a UgUuUAu
1877	CAUGcCU u AGCagcu	2200	UcUuccU c ADGcAaG
1901	uAAaACU C AAGggAc	2201	aagUUUU A UGUcGGC
1912	AuAUagU a GADcagU	2205	UUUAUGU c GGCcugA
1922	UGaAUGU a uAGUua	2210	GgAGaCU c AgUGgcu
1923	uGAUGcU c AgGUaUc	2220	cuggCAU u GuUCUcU
1928	UUAgaGU u UuaCCaG	2224	CucAGGU a UCcauCC
1930	AgAGUuU u aCCaGcU	2226	UgGaUcU C aGGCCgC
1964	GAGACAU u GuCCCCa	2233	CUGaCCU C cuGGAGg
1983	AGGAuAU A CAAGUua	2242	uGGAGCU a gCGaCC
1996	aGGAgaU A CUGagcC	2248	UauCCaU C CAUccCA
2005	UGgAgCU a GCgGaCc	2254	UCCAauU C ACaCUgA
2013	GCUauuU A UUGaGUA	2259	aUCACAU U CAcGGUg
2015	UGCCcAU c GGGgugG	2260	UCACAUU C AcCGUgc
2020	ggUGGuU c UuCUGAG	2266	ggAAuGU C ACCAGGa
2039	gCuGgCU a gCAGaG	2274	ACCAgaU c CuGgaGa
2040	CuGACcU c CuGgAGg	2279	GaAggGU c GUgCAaG
2057	UGcuCCU C CAcAucC	2282	aAGcUGU u ugaGcUG
2061	CuaCCAU c acCgUGU	2288	UAuAaGU U aUggcCU
2071	CACuUGU A GcCUCAg	2291	caGUgGU u CuCUGCu
2076	GUAGCcU C AgAgCua	2321	gAAAGAU C AcAUGGG
2097	CaACuCU U CuUGAuG	2338	UGaGACU c CUgccUG
2098	CACACUU C CccccCG	2339	GaaACcU u UCcUUGG
2115	GCCAGCU c GGaggaU	2341	GACcUcU a ccaGcCu
2128	CaGCUaU u UAUUGAg	2344	UUucyAU c uuCCAAG
2130	cCUGUuU c CUGcCuC	2358	CCcagCU c UCcagCAG
2145	CAACuCU U cuUGAUg	2359	CUGCuUU U gaaCAGA
2152	UauUAuU u UagAgUU	2360	aaCCUUU C CUuuGAA
2156	uugAUGU A UUUUAUa	2376	agUGGgU U cUUCUga
2158	gAUGUAU U UAUUAuU	2377	gUGGgUU c UUCUgag
2159	AUGUAUU U AUUAaUU	2378	agGgUUU c UCUAcuG
2160	UGUAUUU A UUAaUUU	2379	UGcUUUU c ucAUaaG
2162	UAUUUAU U aAUUUag	2380	aAgUUUU a UgUCGGC
2163	AUGUAUU u AUUaaUU	2382	aUUcUcU A UuGcCcC
2166	acUUCAU U cucUAUU	2384	aUcCagU a GaCACAA
2167	AUGuAUU U aUUAAUU	2399	AAaCACU A UgUGGAC
2170	uAUUUaU U AaUUUAag	2401	aaGCUgU u UGagCUG
2171	AgUUUGU u UgcUcCC	2411	uACUGGU c AgGaUgC
2417	gAAUGGU a CAuAcGU	2691	AAuGUcU c cGAGGcC
2418	AcUGGaU C uCAGGcc	2700	GAAgCcU u CCUGCCc
2425	CAugGGU c gAGgGuU	2704	gacCuCU a CCAGCcU
2426	AuuaaUU u AGAGUUU	2711	CCCAGCU c UcagcaG
2433	uAGAGuU U uaCCAGc	2712	gagGuCU c GGAAGGG
2434	AGAGuUU u aCCAGcu	2721	GAAAGGU C gUgCaZG
2448	GAAGCCU U ccUgCcC	2724	GGuaCAU a CGuGUGc
2449	AaGCCUU c cUgCcCC	2744	gUGUGGU c cGUGcAG

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2451	GCCUguU U	CCUgCCU	2750	UAUuUaU u	GAguaAcC
2452	CCUguUU C	CUgCCUc	2759	cCgggaCU u	UCCGaUCCU
2455	gAagCCU u	CCUgCCC	2761	AgGacCU C	aCCcCUGc
2459	CCaCaCU U	CCCCCc	2765	UUUUGCCU C	UGcCgCu
2460	CaCaCUU C	CCCCCcg	2769	agUCCUGU C	AaaCAGG
2479	GAgACCU c	UaccAGC	2797	aUGaAAU C	AUGGUcC
2480	uCACCGU U	GUgAuCC	2803	UCADGGU c	CcagGCg
2483	CCaaUGU c	AGCCACC	2804	ggUGGgU C	cgUGCAG
2484	CUUUUUU c	aCCAguc	2813	CUcCgGU C	cUGACCc
2492	agCACCU C	CCCACCU	2815	aCAGUCC a	cAaCUUU
2504	CCCACcU A	CuUUUgU	2821	cUGACCU c	cUGGaggg
2508	uAUcCAU c	caUcCCA	2822	gGAgCcU c	cGGaCUu
2509	uUAgAgU U	uUaCCAG	2823	ugCCUUU a	GcuCccA
2510	UAgAgUU u	UaCCAGc	2829	cUGGaCU a	uAaUcAU
2520	CuuuUGU U	CcCAADG	2837	AgGUGgU u	CUuCuGa
2521	CAGcaUU u	ACccUcA	2840	UGAgacu C	CugCCUg
2533	UGAugCU C	AGguaUC	2847	CCaAugU c	AGCCaCC
2540	CAGCaGU C	cgcUgUG	2853	gCAGCCU C	uUauGUu
2545	GUgcUGU a	UGGuCcU	2860	gCcaAGU A	aCUUGaA
2568	guGaAgU c	UGuCaAA	2872	GGACCUu c	aGCCaAg
2579	auAAGuU A	UGgCcUG	2877	uUccGCU a	cCAuCAC
2585	cugGCaU U	GUuCCCU	2899	cGgAcuU U	cGADcUU
2588	GCaUUUGU u	CUUaaU	2900	uuAAuUU a	GAgUUUU
2591	UgGUuCU C	UgcUCCU	2904	AcUUcAU U	cUcUaUU
2593	cUUUUUU U	GcuCUGc	2905	cUUcAUU c	UcUaUg
2596	CUuUUUU u	CccaaUG	2906	UUGAUgU a	UUUaUUa
2601	acCgUGU a	UuCGUUU	2907	UGuaUUU a	UUaaUUU
2602	UCCaGcU a	cCAUccC	2908	GAagcUU c	UUUUgcU
2607	cUcGgAU a	UacCUGG	2909	AgcUUcU U	UUGcUcU
2608	caGCAgU c	CgCUGuG	2910	UgUaUUU a	UUaaUUU
2609	gGaAUgU C	ACcaGGA	2911	UgUaUUU a	UUaaUUU
2620	aGGAcCU c	aCcCUgc	2912	UUgUUcU c	UaaUgUC
2626	UUuCGaU c	UUcCAGC	2913	UUUcUcU a	cUggUCA
2628	GCAcAcU U	GuAGCcu	2914	UgcUUUU c	UcaUaAG
2635	UUcAGCU C	CgGUccu	2915	aUUUaUU a	aUUuAGA
2640	ggCCuGU U	UCCUGCc	2916	UaUUcgU U	UcCgGAG
2641	cCCAGcU c	uCaGCAG	2917	aUUcgUU U	cCgGAGA
2642	CCuGUUU C	CUGCcuC	2918	UUcgUUU c	CgGAGAg
2653	uAcUGgU C	AGGaUgC	2919	UUcUcaU a	AGgGuCG
2659	gaAGGGU C	gUGCAAG	2931	ugGaGGU C	UCCgAAg
2689	CuAAuGU c	UccGAGG	2933	GaGGUCU C	GgAAggg
2941	GagACAU U	GuCCccA			
2951	CCAagCU a	CCUcUGc			
2952	CAGcagU C	CgcUGUG			
2955	AgUgaCU c	UGUGUcA			
2956	uUUCCUU U	GaaUcAa			
2961	UcUGUGU c	AGccAcU			
2962	aUGUaUU u	aUUAAUu			
2965	UUUGaAU c	AAUAAAG			

2966	GcUgGcU	A	gcAgAGg
2969	laUcAAD	A	AAGuUUU
2975	UAgAGuU	U	UacCAgC
2976	gAgGgUU	U	CUUuACU
2977	AAGCUgU	u	UgAgCUG
2979	uCaUUUU	C	uAuUGCC

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Table 4  
Human ICAM HH Ribozyme Sequences

nt. Position	Ribozyme Sequence
11	CAGGUC CUGAUGAGGCCGAAAGGCCGAA ACUGGG
23	AGCAGAG CUGAUGAGGCCGAAAGGCCGAA AGCUCAG
26	AGUAGCA CUGAUGAGGCCGAAAGGCCGAA AGGAGCU
31	CUCUGAG CUGAUGAGGCCGAAAGGCCGAA AGCAGAG
34	CAACUCU CUGAUGAGGCCGAAAGGCCGAA AGUAGCA
40	AGGUUGC CUGAUGAGGCCGAAAGGCCGAA ACUCUGA
48	CGAGGCU CUGAUGAGGCCGAAAGGCCGAA AGGUUGC
54	CCAUAGC CUGAUGAGGCCGAAAGGCCGAA AGGCUGA
58	GGAGCCA CUGAUGAGGCCGAAAGGCCGAA AGCGAGG
64	CUGCUGG CUGAUGAGGCCGAAAGGCCGAA AGCCAUT
96	GGACCAG CUGAUGAGGCCGAAAGGCCGAA AGUGCGG
102	CGAGCAG CUGAUGAGGCCGAAAGGCCGAA ACCAGGA
108	GAGCCOC CUGAUGAGGCCGAAAGGCCGAA AGCAGGA
115	GGGAACA CUGAUGAGGCCGAAAGGCCGAA AGCCCCG
119	UCCUGGG CUGAUGAGGCCGAAAGGCCGAA ACAGAGC
120	GUCCUGG CUGAUGAGGCCGAAAGGCCGAA AACAGAG
146	GGACACA CUGAUGAGGCCGAAAGGCCGAA AUGGUCG
152	UGAGGGG CUGAUGAGGCCGAAAGGCCGAA ACACAGA
158	GACUUUU CUGAUGAGGCCGAAAGGCCGAA AGGGGGA
165	GCAGGAU CUGAUGAGGCCGAAAGGCCGAA ACUUUUG
168	GGGCGAG CUGAUGAGGCCGAAAGGCCGAA AUGACUU
185	CAGCACG CUGAUGAGGCCGAAAGGCCGAA AGCCUCC
209	GUACAG CUGAUGAGGCCGAAAGGCCGAA AGGUGCU
227	GCCCAAC CUGAUGAGGCCGAAAGGCCGAA ACUUGGG
230	UAUGCCC CUGAUGAGGCCGAAAGGCCGAA ACAACUU
237	GGGUCUC CUGAUGAGGCCGAAAGGCCGAA AUGCCCA
248	UUUAGGC CUGAUGAGGCCGAAAGGCCGAA ACCGGGU
253	UCCUUUU CUGAUGAGGCCGAAAGGCCGAA AGGCAAC
263	CAGGAGC CUGAUGAGGCCGAAAGGCCGAA ACUCUUU
267	CAGGCAG CUGAUGAGGCCGAAAGGCCGAA AGCAACU
293	CAGUUCA CUGAUGAGGCCGAAAGGCCGAA ACACCUU
319	GGUUGGC CUGAUGAGGCCGAAAGGCCGAA AUCUUCU
335	GUUUGAA CUGAUGAGGCCGAAAGGCCGAA AGCACAU
337	CAGUUUG CUGAUGAGGCCGAAAGGCCGAA AUAGCAC
338	GCAGUUU CUGAUGAGGCCGAAAGGCCGAA AAUAGCA
359	AGCUGUU CUGAUGAGGCCGAAAGGCCGAA ACUGCCC
367	AAGGUUU CUGAUGAGGCCGAAAGGCCGAA AGCUGUU
374	GGUGAGG CUGAUGAGGCCGAAAGGCCGAA AGGUUUU
375	CGGUGAG CUGAUGAGGCCGAAAGGCCGAA AAGGUUU
378	ACACGGU CUGAUGAGGCCGAAAGGCCGAA AGGAAGG
386	AGUCCAG CUGAUGAGGCCGAAAGGCCGAA ACACGGU
394	CGUUCUG CUGAUGAGGCCGAAAGGCCGAA AGUCCAG
420	AAGAGGG CUGAUGAGGCCGAAAGGCCGAA AGGGGUG
425	CUGCCAA CUGAUGAGGCCGAAAGGCCGAA AGGGGAG

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427	GGCUGCC	CUGADGAGGCCGAAAGGCCGAA	AGAGGGG
450	GUAGGGU	CUGADGAGGCCGAAAGGCCGAA	AGGUUCU
451	CGUAGGG	CUGADGAGGCCGAAAGGCCGAA	AAGGUUC
456	GGCAGCG	CUGADGAGGCCGAAAGGCCGAA	AGGUTAA
495	CCACGGU	CUGADGAGGCCGAAAGGCCGAA	AGGUUGG
510	CCCCACG	CUGADGAGGCCGAAAGGCCGAA	AGCAGCA
564	UGGUCCU	CUGADGAGGCCGAAAGGCCGAA	ACCCACG
592	CCAUGGU	CUGADGAGGCCGAAAGGCCGAA	ADCUCUC
607	CACGAGA	CUGADGAGGCCGAAAGGCCGAA	AUUGGCU
608	GCACGAG	CUGADGAGGCCGAAAGGCCGAA	AAUUGGC
609	GGCACGA	CUGADGAGGCCGAAAGGCCGAA	AAAUUGG
611	GCGGCAC	CUGADGAGGCCGAAAGGCCGAA	AGAAAUU
656	GUUCUCA	CUGADGAGGCCGAAAGGCCGAA	ACAGCUC
657	UGUUCUC	CUGADGAGGCCGAAAGGCCGAA	AACAGCU
668	GGGGGCC	CUGADGAGGCCGAAAGGCCGAA	AGGUGOU
677	GAGCUGG	CUGADGAGGCCGAAAGGCCGAA	AGGGGGC
684	AGGUCUG	CUGADGAGGCCGAAAGGCCGAA	AGCUGGU
692	CAGGACA	CUGADGAGGCCGAAAGGCCGAA	AGGUCUG
693	GCAGGAC	CUGADGAGGCCGAAAGGCCGAA	AAGGUCU
696	CUGGCAG	CUGADGAGGCCGAAAGGCCGAA	ACAAAGG
709	UGUGGGG	CUGADGAGGCCGAAAGGCCGAA	AGUCGCU
720	GGCUGAC	CUGADGAGGCCGAAAGGCCGAA	AGUUGUG
723	GGGGGCU	CUGADGAGGCCGAAAGGCCGAA	ACAAGUU
735	CCUCUAG	CUGADGAGGCCGAAAGGCCGAA	ACCCGGG
738	CCACCCU	CUGADGAGGCCGAAAGGCCGAA	AGGACCC
765	GGGAACA	CUGADGAGGCCGAAAGGCCGAA	ACCAACG
769	UCCAGGG	CUGADGAGGCCGAAAGGCCGAA	ACAGACC
770	GUCCAGG	CUGADGAGGCCGAAAGGCCGAA	AACAGAC
785	GACUGGG	CUGADGAGGCCGAAAGGCCGAA	ACAGCCC
786	AGACUGG	CUGADGAGGCCGAAAGGCCGAA	AACAGCC
792	CCUCCGA	CUGADGAGGCCGAAAGGCCGAA	ACUGGGA
794	GGCCUCC	CUGADGAGGCCGAAAGGCCGAA	AGACUGG
807	CCAGGUG	CUGADGAGGCCGAAAGGCCGAA	ACCUUGG
833	GGGGUUC	CUGADGAGGCCGAAAGGCCGAA	ACUCUCG
846	CADAGGU	CUGADGAGGCCGAAAGGCCGAA	ACUGUGG
851	GUUGCCA	CUGADGAGGCCGAAAGGCCGAA	AGGUGAC
863	CGAGAAG	CUGADGAGGCCGAAAGGCCGAA	AGUCGUT
866	GGCCGAG	CUGADGAGGCCGAAAGGCCGAA	AGGAGUC
867	UGGCCGA	CUGADGAGGCCGAAAGGCCGAA	AAGGAGU
869	CUUGGCC	CUGADGAGGCCGAAAGGCCGAA	AGAAGGA
881	ACUGACT	CUGADGAGGCCGAAAGGCCGAA	AGGCCUU
885	UCACACT	CUGADGAGGCCGAAAGGCCGAA	ACUGAGG
933	CCAGUAT	CUGADGAGGCCGAAAGGCCGAA	ACUGCAC
936	UCCCCAG	CUGADGAGGCCGAAAGGCCGAA	AUTACUG
978	AGCUGUA	CUGADGAGGCCGAAAGGCCGAA	AUGGUCA
980	AAAGCUG	CUGADGAGGCCGAAAGGCCGAA	AGAUGGU
986	CGCCGGA	CUGADGAGGCCGAAAGGCCGAA	AGCUGUA
987	GCGCCGG	CUGADGAGGCCGAAAGGCCGAA	AAGCUGU
988	GGGCCCG	CUGADGAGGCCGAAAGGCCGAA	AAAGCUG

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1005	UCGUCAG	CUGAUGAGGCGGAAAGGCGGAA	AUCAAGU
1006	UUCGUCA	CUGAUGAGGCGGAAAGGCGGAA	AADCAAG
1023	CUUCUGA	CUGAUGAGGCGGAAAGGCGGAA	ACCUUCG
1025	CCUUCU	CUGAUGAGGCGGAAAGGCGGAA	AGACUUC
1066	UUGGUC	CUGAUGAGGCGGAAAGGCGGAA	AGGUGG
1092	GGGUGG	CUGAUGAGGCGGAAAGGCGGAA	ACCCCAU
1093	UGGGUG	CUGAUGAGGCGGAAAGGCGGAA	AACCCA
1125	UCAGCAG	CUGAUGAGGCGGAAAGGCGGAA	AGCUUGG
1163	GCAGGAG	CUGAUGAGGCGGAAAGGCGGAA	AGCUUGG
1164	AGCAGGA	CUGAUGAGGCGGAAAGGCGGAA	AAGCUGC
1166	AGAGCAG	CUGAUGAGGCGGAAAGGCGGAA	AGAAGCU
1172	GGUUGCA	CUGAUGAGGCGGAAAGGCGGAA	AGCAGGA
1200	UGUGUAU	CUGAUGAGGCGGAAAGGCGGAA	AGCUUGG
1201	UUGUGUA	CUGAUGAGGCGGAAAGGCGGAA	AAGCUGG
1203	UCUUGUG	CUGAUGAGGCGGAAAGGCGGAA	AUAAGCU
1227	GGACACG	CUGAUGAGGCGGAAAGGCGGAA	AGCUCCC
1228	AGGACAC	CUGAUGAGGCGGAAAGGCGGAA	AAGCUCC
1233	CADACAG	CUGAUGAGGCGGAAAGGCGGAA	ACAAGAA
1238	GGGGCCA	CUGAUGAGGCGGAAAGGCGGAA	ACAGGAC
1264	CCCGGAC	CUGAUGAGGCGGAAAGGCGGAA	AUCCUUC
1267	UUUCCCG	CUGAUGAGGCGGAAAGGCGGAA	ACAADCC
1294	UGCUGGG	CUGAUGAGGCGGAAAGGCGGAA	AUUUUUU
1295	CUGCUGG	CUGAUGAGGCGGAAAGGCGGAA	AUUUUUC
1306	CACAUUG	CUGAUGAGGCGGAAAGGCGGAA	AGUCUUG
1321	UUCCCCC	CUGAUGAGGCGGAAAGGCGGAA	AGCUUGG
1334	CUCGGGC	CUGAUGAGGCGGAAAGGCGGAA	AUGGCUU
1344	GACACUU	CUGAUGAGGCGGAAAGGCGGAA	AGCUUGG
1351	UCCUUUA	CUGAUGAGGCGGAAAGGCGGAA	ACACUUG
1353	CAUCCUU	CUGAUGAGGCGGAAAGGCGGAA	AGACACU
1366	AGUGGGA	CUGAUGAGGCGGAAAGGCGGAA	AGUGCCA
1367	CAGUGGG	CUGAUGAGGCGGAAAGGCGGAA	AAGUGCC
1368	GCAGUGG	CUGAUGAGGCGGAAAGGCGGAA	AAAGUGC
1380	AUUCCCC	CUGAUGAGGCGGAAAGGCGGAA	AUGGGCA
1388	AGUCACU	CUGAUGAGGCGGAAAGGCGGAA	AUUCCCC
1398	CUCGAGU	CUGAUGAGGCGGAAAGGCGGAA	ACAGUCA
1402	AGAUCUC	CUGAUGAGGCGGAAAGGCGGAA	AGUGACA
1408	CCCUCAA	CUGAUGAGGCGGAAAGGCGGAA	AUCUCGA
1410	UGCCUUC	CUGAUGAGGCGGAAAGGCGGAA	AGAUUCU
1421	ACAGAGG	CUGAUGAGGCGGAAAGGCGGAA	AGGUGCC
1425	CCCGACA	CUGAUGAGGCGGAAAGGCGGAA	AGGUAGG
1429	CUGGCCC	CUGAUGAGGCGGAAAGGCGGAA	ACAGAGG
1444	UCCCCUU	CUGAUGAGGCGGAAAGGCGGAA	AGUGCUC
1455	CGCGGGU	CUGAUGAGGCGGAAAGGCGGAA	ACCUCCC
1482	GGGGGGA	CUGAUGAGGCGGAAAGGCGGAA	AGCACAU
1484	CCGGGGG	CUGAUGAGGCGGAAAGGCGGAA	AGAGCAC
1493	AAUCUCA	CUGAUGAGGCGGAAAGGCGGAA	ACCGGGG
1500	UGAUGAC	CUGAUGAGGCGGAAAGGCGGAA	AUCUCAU
1503	UGAUGAU	CUGAUGAGGCGGAAAGGCGGAA	ACAAUCU
1506	CAGUGAU	CUGAUGAGGCGGAAAGGCGGAA	AUGACAA

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1509	CCACAGU	CUGADGAGGCCGAAAGGCCGAA	AUGADGA
1518	CGGCTUG	CUGADGAGGCCGAAAGGCCGAA	ACCACAG
1530	CCAUAU	CUGADGAGGCCGAAAGGCCGAA	ACUGCGG
1533	UGCCAU	CUGADGAGGCCGAAAGGCCGAA	AUGACUG
1551	ACGUGCU	CUGADGAGGCCGAAAGGCCGAA	AGGCCUG
1559	AUAGAGG	CUGADGAGGCCGAAAGGCCGAA	ACGUGCU
1563	GGUUAUA	CUGADGAGGCCGAAAGGCCGAA	AGGUACG
1565	GCGGUA	CUGADGAGGCCGAAAGGCCGAA	AGAGGUA
1567	UGCGGU	CUGADGAGGCCGAAAGGCCGAA	AUAGAGG
1584	AUUUCUU	CUGADGAGGCCGAAAGGCCGAA	AUCUCC
1592	UAGUCUG	CUGADGAGGCCGAAAGGCCGAA	AUUUCUU
1599	CCUGUUG	CUGADGAGGCCGAAAGGCCGAA	AGUCUGU
1651	GUUCAGG	CUGADGAGGCCGAAAGGCCGAA	AGGCGUG
1661	CCCGGA	CUGADGAGGCCGAAAGGCCGAA	AGGUCA
1663	GUCCCG	CUGADGAGGCCGAAAGGCCGAA	AUAGGU
1678	CGAGGAA	CUGADGAGGCCGAAAGGCCGAA	AGGCCU
1680	GCCGAGG	CUGADGAGGCCGAAAGGCCGAA	AGAGGCC
1681	GGCCGAG	CUGADGAGGCCGAAAGGCCGAA	AAGAGGC
1684	GAAGGCC	CUGADGAGGCCGAAAGGCCGAA	AGGAGA
1690	AUAUGGG	CUGADGAGGCCGAAAGGCCGAA	AGGCCA
1691	AADAUGG	CUGADGAGGCCGAAAGGCCGAA	AAGGCCG
1696	CCACCA	CUGADGAGGCCGAAAGGCCGAA	AUGCGAA
1698	UGCCACC	CUGADGAGGCCGAAAGGCCGAA	AUAUGGG
1737	CAUGGCA	CUGADGAGGCCGAAAGGCCGAA	AUGUCUU
1750	GUAGGUG	CUGADGAGGCCGAAAGGCCGAA	AGUGCA
1756	GGGCCGG	CUGADGAGGCCGAAAGGCCGAA	AGGUGUA
1787	UGAGGAC	CUGADGAGGCCGAAAGGCCGAA	AUGCCU
1790	GACUGAG	CUGADGAGGCCGAAAGGCCGAA	ACAADGC
1793	UCUGACT	CUGADGAGGCCGAAAGGCCGAA	AGGACA
1797	UGUAUCU	CUGADGAGGCCGAAAGGCCGAA	ACUGAGG
1802	GCUGUUG	CUGADGAGGCCGAAAGGCCGAA	AUCUGAC
1812	GGCCCCA	CUGADGAGGCCGAAAGGCCGAA	AUGCUGU
1813	UGGCCCC	CUGADGAGGCCGAAAGGCCGAA	AAGCUG
1825	GUGCAGG	CUGADGAGGCCGAAAGGCCGAA	ACCAUGG
1837	AGUGUUU	CUGADGAGGCCGAAAGGCCGAA	AGGUGUG
1845	CGGGGCC	CUGADGAGGCCGAAAGGCCGAA	AGUGUUU
1856	CAGAUCA	CUGADGAGGCCGAAAGGCCGAA	AUGCGUG
1861	GACUACA	CUGADGAGGCCGAAAGGCCGAA	AUCAGAU
1865	AUGUGAC	CUGADGAGGCCGAAAGGCCGAA	ACAGAU
1868	GUCAUGU	CUGADGAGGCCGAAAGGCCGAA	ACUACAG
1877	CUUGGCU	CUGADGAGGCCGAAAGGCCGAA	AGUCAUG
1901	AUGUCUU	CUGADGAGGCCGAAAGGCCGAA	AGUCUUG
1912	AUCCADC	CUGADGAGGCCGAAAGGCCGAA	AUCAUGU
1922	AGACUUU	CUGADGAGGCCGAAAGGCCGAA	ACADCCA
1923	UAGACUU	CUGADGAGGCCGAAAGGCCGAA	AACAUCC
1928	CAGGCUA	CUGADGAGGCCGAAAGGCCGAA	ACUUUA
1930	AUCAGGC	CUGADGAGGCCGAAAGGCCGAA	AGACUUU
1964	GUGGGGC	CUGADGAGGCCGAAAGGCCGAA	AUGUCUC
1983	CCAGUUG	CUGADGAGGCCGAAAGGCCGAA	AUGUCU

1996	GUUUCAG	CUGAUGAGGCCGAAAGGCCGAA	AUUUCCC
2005	AGGCAGC	CUGAUGAGGCCGAAAGGCCGAA	AGUUUCA
2013	UACCCAA	CUGAUGAGGCCGAAAGGCCGAA	AGGCAGC
2015	CAUACCC	CUGAUGAGGCCGAAAGGCCGAA	AUAAGCA
2020	CUCAGCA	CUGAUGAGGCCGAAAGGCCGAA	ACCCAAU
2039	CUUCUGU	CUGAUGAGGCCGAAAGGCCGAA	AGUCUGU
2040	UCUUCUG	CUGAUGAGGCCGAAAGGCCGAA	AAGUCUG
2057	GUCUADG	CUGAUGAGGCCGAAAGGCCGAA	AGGGCCA
2061	ACAUUGC	CUGAUGAGGCCGAAAGGCCGAA	AUGGAGG
2071	UUGAUGC	CUGAUGAGGCCGAAAGGCCGAA	ACACADG
2076	GGGUUUU	CUGAUGAGGCCGAAAGGCCGAA	AUGCUCU
2097	CGUCAGG	CUGAUGAGGCCGAAAGGCCGAA	AGUGUGG
2098	CGUCAG	CUGAUGAGGCCGAAAGGCCGAA	AAGUGUG
2115	AGUGCCC	CUGAUGAGGCCGAAAGGCCGAA	AGCUGGC
2128	GUCAGUA	CUGAUGAGGCCGAAAGGCCGAA	ACAGCAG
2130	GGGUCAG	CUGAUGAGGCCGAAAGGCCGAA	AGACAGC
2145	UAUCAUC	CUGAUGAGGCCGAAAGGCCGAA	AGGGUUG
2152	AAADACA	CUGAUGAGGCCGAAAGGCCGAA	AUCAUCA
2156	GAUAAA	CUGAUGAGGCCGAAAGGCCGAA	ACAUUUC
2158	AUGAAUA	CUGAUGAGGCCGAAAGGCCGAA	AUACAUA
2159	AAUGAAU	CUGAUGAGGCCGAAAGGCCGAA	AAUACAU
2160	AAAUCAA	CUGAUGAGGCCGAAAGGCCGAA	AAAUACA
2162	ACAAADG	CUGAUGAGGCCGAAAGGCCGAA	AUAUAUA
2163	AACAAAU	CUGAUGAGGCCGAAAGGCCGAA	AAUAAAU
2166	AAUAACA	CUGAUGAGGCCGAAAGGCCGAA	AUGAAUA
2167	AAAUAAC	CUGAUGAGGCCGAAAGGCCGAA	AAUGAAU
2170	GUAAAAU	CUGAUGAGGCCGAAAGGCCGAA	ACAAAUU
2171	GGUAAAA	CUGAUGAGGCCGAAAGGCCGAA	AACAAAU
2173	CUUGUAA	CUGAUGAGGCCGAAAGGCCGAA	AUAACAA
2174	GCUGGUA	CUGAUGAGGCCGAAAGGCCGAA	AAUAACA
2175	AGCUGGU	CUGAUGAGGCCGAAAGGCCGAA	AAAUAAC
2176	UAGCUGG	CUGAUGAGGCCGAAAGGCCGAA	AAAUAUA
2183	CAAUAAA	CUGAUGAGGCCGAAAGGCCGAA	AGCUGGU
2185	CUCAAUA	CUGAUGAGGCCGAAAGGCCGAA	AUAGCUG
2186	ACUCAAU	CUGAUGAGGCCGAAAGGCCGAA	AAUAGCU
2187	CACUCAA	CUGAUGAGGCCGAAAGGCCGAA	AAAUAGC
2189	GACACUC	CUGAUGAGGCCGAAAGGCCGAA	AUAUAUA
2196	CAUAAA	CUGAUGAGGCCGAAAGGCCGAA	ACACUCA
2198	UACAUAA	CUGAUGAGGCCGAAAGGCCGAA	AGACACU
2199	CUACAUA	CUGAUGAGGCCGAAAGGCCGAA	AAGACAC
2200	CCUACAU	CUGAUGAGGCCGAAAGGCCGAA	AAAGACA
2201	GCCUACA	CUGAUGAGGCCGAAAGGCCGAA	AAAAGAC
2205	UUUAGCC	CUGAUGAGGCCGAAAGGCCGAA	ACAUAAA
2210	GUUCAUU	CUGAUGAGGCCGAAAGGCCGAA	AGCCUAC
2220	AGAGACC	CUGAUGAGGCCGAAAGGCCGAA	AUGUUCA
2224	GGCCAGA	CUGAUGAGGCCGAAAGGCCGAA	ACCUADG
2226	GAGGCCA	CUGAUGAGGCCGAAAGGCCGAA	AGACCUA
2233	GCUCUGU	CUGAUGAGGCCGAAAGGCCGAA	AGGCCAG
2242	GGACUGG	CUGAUGAGGCCGAAAGGCCGAA	AGCUCUG

2248	UGACAG	CUGAUGAGGCCGAAAGGCCGAA	ACUGGGA
2254	UGAAGU	CUGAUGAGGCCGAAAGGCCGAA	ACAUGGA
2259	GACCUU	CUGAUGAGGCCGAAAGGCCGAA	AUGUGAC
2260	UGACCU	CUGAUGAGGCCGAAAGGCCGAA	AAUGUGA
2266	ACCUUG	CUGAUGAGGCCGAAAGGCCGAA	ACCUUGA
2274	ACAACU	CUGAUGAGGCCGAAAGGCCGAA	ACCUUGU
2279	CCTGUAC	CUGAUGAGGCCGAAAGGCCGAA	ACUGUAC
2282	CAACCU	CUGAUGAGGCCGAAAGGCCGAA	ACAACUG
2288	AGUGUAC	CUGAUGAGGCCGAAAGGCCGAA	ACCUUGA
2291	UGCAGU	CUGAUGAGGCCGAAAGGCCGAA	ACAAACU
2321	CCCAUU	CUGAUGAGGCCGAAAGGCCGAA	AUCUUUU
2338	CAADGAG	CUGAUGAGGCCGAAAGGCCGAA	AGUCCCA
2339	CCAUGA	CUGAUGAGGCCGAAAGGCCGAA	AAGUCCC
2341	GGCCAU	CUGAUGAGGCCGAAAGGCCGAA	AGAAUUC
2344	GUUGGCC	CUGAUGAGGCCGAAAGGCCGAA	AUGAGAA
2358	CUGGGGA	CUGAUGAGGCCGAAAGGCCGAA	AGGCAGG
2359	UCUGGGG	CUGAUGAGGCCGAAAGGCCGAA	AAGGCAG
2360	UUCUGGG	CUGAUGAGGCCGAAAGGCCGAA	AAAGGCA
2376	AUAGAAA	CUGAUGAGGCCGAAAGGCCGAA	AUCACUC
2377	GADAGAA	CUGAUGAGGCCGAAAGGCCGAA	AAUCACU
2378	CGAUGA	CUGAUGAGGCCGAAAGGCCGAA	AAAUAC
2379	CCGAUAG	CUGAUGAGGCCGAAAGGCCGAA	AAAAUCA
2380	GCCGAUA	CUGAUGAGGCCGAAAGGCCGAA	AAAAAUC
2382	GUGCCGA	CUGAUGAGGCCGAAAGGCCGAA	AGAAAAA
2384	UUGUGCC	CUGAUGAGGCCGAAAGGCCGAA	AUAGAAA
2399	GUCCAUA	CUGAUGAGGCCGAAAGGCCGAA	AGUGCUU
2401	CAGUCCA	CUGAUGAGGCCGAAAGGCCGAA	AUAGUGC
2411	GAACCAU	CUGAUGAGGCCGAAAGGCCGAA	ACCAGUC
2417	ACCUUG	CUGAUGAGGCCGAAAGGCCGAA	ACCAUUA
2418	AAACCUU	CUGAUGAGGCCGAAAGGCCGAA	AAACAUU
2425	AUCUCUG	CUGAUGAGGCCGAAAGGCCGAA	ACCUUGG
2426	AAUCUCU	CUGAUGAGGCCGAAAGGCCGAA	AAACUUG
2433	ACUGGGU	CUGAUGAGGCCGAAAGGCCGAA	AUCUCUG
2434	CACUGGG	CUGAUGAGGCCGAAAGGCCGAA	AAUCUCU
2448	GAGGAUU	CUGAUGAGGCCGAAAGGCCGAA	AGGCCUC
2449	GGAGGAA	CUGAUGAGGCCGAAAGGCCGAA	AAGGCCU
2451	AGGGAGG	CUGAUGAGGCCGAAAGGCCGAA	AUAAGGC
2452	AAGGGAG	CUGAUGAGGCCGAAAGGCCGAA	AAUAAGG
2455	GGGAAGG	CUGAUGAGGCCGAAAGGCCGAA	AGGAUUA
2459	UGGGGGG	CUGAUGAGGCCGAAAGGCCGAA	AGGGAGG
2460	UUGGGGG	CUGAUGAGGCCGAAAGGCCGAA	AAGGGAG
2479	GCUAACA	CUGAUGAGGCCGAAAGGCCGAA	AGGUGUC
2480	GGCUAAC	CUGAUGAGGCCGAAAGGCCGAA	AAGGUGU
2483	GGUGGCU	CUGAUGAGGCCGAAAGGCCGAA	ACAAAGG
2484	AGGUGGC	CUGAUGAGGCCGAAAGGCCGAA	AACAAGG
2492	GGGUGGG	CUGAUGAGGCCGAAAGGCCGAA	AGGUGGC
2504	AGAAADG	CUGAUGAGGCCGAAAGGCCGAA	AUGUGGG
2508	UGGCAGA	CUGAUGAGGCCGAAAGGCCGAA	AUGUADG
2509	CUGGCAG	CUGAUGAGGCCGAAAGGCCGAA	AAUGUAD

2510	ACUGGCA	CUGAUGAGGCGAAAGGCGGAA	AAADGUA
2520	CAUUGUG	CUGAUGAGGCGAAAGGCGGAA	ACACUGG
2521	UCAUUGU	CUGAUGAGGCGAAAGGCGGAA	AACACUG
2533	GACCGCU	CUGAUGAGGCGAAAGGCGGAA	AGUGUCA
2540	CAGACAU	CUGAUGAGGCGAAAGGCGGAA	ACCGCTG
2545	AUGUCCA	CUGAUGAGGCGAAAGGCGGAA	ACADGAC
2568	UUGGGCA	CUGAUGAGGCGAAAGGCGGAA	AUOCCCU
2579	CAAGGCA	CUGAUGAGGCGAAAGGCGGAA	AGCUUGG
2585	AGAGGAC	CUGAUGAGGCGAAAGGCGGAA	AGGCADA
2588	ACAAGAG	CUGAUGAGGCGAAAGGCGGAA	ACAAGGC
2591	AGGACAA	CUGAUGAGGCGAAAGGCGGAA	AGGACAA
2593	ACAGGAC	CUGAUGAGGCGAAAGGCGGAA	AGAGGAC
2596	CAAAACAG	CUGAUGAGGCGAAAGGCGGAA	ACAAGAG
2601	AAADGCA	CUGAUGAGGCGAAAGGCGGAA	ACAGGAC
2602	GAAAUGC	CUGAUGAGGCGAAAGGCGGAA	AACAGGA
2607	CCAGUGA	CUGAUGAGGCGAAAGGCGGAA	AUGCAAA
2608	CCCAGUG	CUGAUGAGGCGAAAGGCGGAA	AAUGCAA
2609	UCCCAU	CUGAUGAGGCGAAAGGCGGAA	AAADGCA
2620	AUAGUGC	CUGAUGAGGCGAAAGGCGGAA	AGCOCOC
2626	GCUGCAA	CUGAUGAGGCGAAAGGCGGAA	AGUGCAA
2628	GAGCUGC	CUGAUGAGGCGAAAGGCGGAA	AUAGUGC
2635	GAAACUG	CUGAUGAGGCGAAAGGCGGAA	AGCUGCA
2640	UGCAGGA	CUGAUGAGGCGAAAGGCGGAA	ACUGGAG
2641	CUGCAGG	CUGAUGAGGCGAAAGGCGGAA	AACUGGA
2642	ACUGCAG	CUGAUGAGGCGAAAGGCGGAA	AAACUGG
2653	GGACCCU	CUGAUGAGGCGAAAGGCGGAA	AUCACUG
2659	CUUGCAG	CUGAUGAGGCGAAAGGCGGAA	ACCCUGA
2689	CCUCCAA	CUGAUGAGGCGAAAGGCGGAA	ACCUUGG
2691	GUCCUCC	CUGAUGAGGCGAAAGGCGGAA	AUAUCCU
2700	UGGGAGG	CUGAUGAGGCGAAAGGCGGAA	AGUCCUC
2704	AAGCUGG	CUGAUGAGGCGAAAGGCGGAA	AGGGAGU
2711	CCUCCCA	CUGAUGAGGCGAAAGGCGGAA	AGCUGGG
2712	CCCUUCC	CUGAUGAGGCGAAAGGCGGAA	AAGCUGG
2721	CGCGGAU	CUGAUGAGGCGAAAGGCGGAA	ACCCUUC
2724	ACACGGG	CUGAUGAGGCGAAAGGCGGAA	AUGACCC
2744	CUACACA	CUGAUGAGGCGAAAGGCGGAA	ACACACA
2750	GCUGUC	CUGAUGAGGCGAAAGGCGGAA	ACACADA
2759	AGAGCGA	CUGAUGAGGCGAAAGGCGGAA	AGCUUGU
2761	ACAGAGC	CUGAUGAGGCGAAAGGCGGAA	AGAGCUU
2765	GGUGACA	CUGAUGAGGCGAAAGGCGGAA	AGCGAGA
2769	CCUGGGU	CUGAUGAGGCGAAAGGCGGAA	ACAGAGC
2797	GAAACAU	CUGAUGAGGCGAAAGGCGGAA	AUUGCAC
2803	UGCAGUG	CUGAUGAGGCGAAAGGCGGAA	ACCAUGA
2804	CUGCAGU	CUGAUGAGGCGAAAGGCGGAA	AACAUG
2813	AGGUCAA	CUGAUGAGGCGAAAGGCGGAA	ACUGCAG
2815	AAAGGUC	CUGAUGAGGCGAAAGGCGGAA	AGACTGC
2821	AGCCCAA	CUGAUGAGGCGAAAGGCGGAA	AGGUCAA
2822	GAGCCCA	CUGAUGAGGCGAAAGGCGGAA	AAGGUCA
2823	UGAGCCC	CUGAUGAGGCGAAAGGCGGAA	AAAGGUC

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2829	AUCACUU	CUGAUGAGGCCGAAAGGCCGAA	AGGCCAA
2837	GUGGGAG	CUGAUGAGGCCGAAAGGCCGAA	AUCACUU
2840	GAGGGG	CUGAUGAGGCCGAAAGGCCGAA	AGGAUCA
2847	GGAGGCU	CUGAUGAGGCCGAAAGGCCGAA	AGGUGGG
2853	UACUCAG	CUGAUGAGGCCGAAAGGCCGAA	AGGCUGA
2860	UCCAGC	CUGAUGAGGCCGAAAGGCCGAA	ACTCAGG
2872	GUGAGCC	CUGAUGAGGCCGAAAGGCCGAA	AUGGUCC
2877	GUGUUGU	CUGAUGAGGCCGAAAGGCCGAA	AGCCUAU
2899	AAAAUCA	CUGAUGAGGCCGAAAGGCCGAA	AUUUGCC
2900	AAAAAUC	CUGAUGAGGCCGAAAGGCCGAA	AAUUUGC
2904	AAAAAAA	CUGAUGAGGCCGAAAGGCCGAA	AUCAAAU
2905	AAAAAAA	CUGAUGAGGCCGAAAGGCCGAA	AAUCAAA
2906	AAAAAAA	CUGAUGAGGCCGAAAGGCCGAA	AAAUCAA
2907	AAAAAAA	CUGAUGAGGCCGAAAGGCCGAA	AAAAUCA
2908	AAAAAAA	CUGAUGAGGCCGAAAGGCCGAA	AAAAAUC
2909	AAAAAAA	CUGAUGAGGCCGAAAGGCCGAA	AAAAAAU
2910	AAAAAAA	CUGAUGAGGCCGAAAGGCCGAA	AAAAAAA
2911	AAAAAAA	CUGAUGAGGCCGAAAGGCCGAA	AAAAAAA
2912	GAAAAAA	CUGAUGAGGCCGAAAGGCCGAA	AAAAAAA
2913	UGAAAAA	CUGAUGAGGCCGAAAGGCCGAA	AAAAAAA
2914	CUGAAAA	CUGAUGAGGCCGAAAGGCCGAA	AAAAAAA
2915	UCUGAAA	CUGAUGAGGCCGAAAGGCCGAA	AAAAAAA
2916	CUCUGAA	CUGAUGAGGCCGAAAGGCCGAA	AAAAAAA
2917	UCUCUGA	CUGAUGAGGCCGAAAGGCCGAA	AAAAAAA
2918	GUCUCUG	CUGAUGAGGCCGAAAGGCCGAA	AAAAAAA
2919	CGUCUCU	CUGAUGAGGCCGAAAGGCCGAA	AAAAAAA
2931	GUUGCGA	CUGAUGAGGCCGAAAGGCCGAA	ACCCCGU
2933	AUGUUGC	CUGAUGAGGCCGAAAGGCCGAA	AGACCCC
2941	UCUGGGC	CUGAUGAGGCCGAAAGGCCGAA	AUGUUGC
2951	ACAAAGG	CUGAUGAGGCCGAAAGGCCGAA	AGUCUGG
2952	CACAAAG	CUGAUGAGGCCGAAAGGCCGAA	AAGUCUG
2955	UACACA	CUGAUGAGGCCGAAAGGCCGAA	AGGAAGU
2956	CURACAC	CUGAUGAGGCCGAAAGGCCGAA	AAGGAAG
2961	AUUAACU	CUGAUGAGGCCGAAAGGCCGAA	ACACAAA
2962	UAUUAAC	CUGAUGAGGCCGAAAGGCCGAA	AACACAA
2965	CUUUAUU	CUGAUGAGGCCGAAAGGCCGAA	ACTUACA
2966	GCUUUAU	CUGAUGAGGCCGAAAGGCCGAA	AACUAAC
2969	AAAGCUU	CUGAUGAGGCCGAAAGGCCGAA	AUUAACU
2975	GUUGAGA	CUGAUGAGGCCGAAAGGCCGAA	AGCUUUA
2976	AGUUGAG	CUGAUGAGGCCGAAAGGCCGAA	AAGCUUU
2977	CAGUUGA	CUGAUGAGGCCGAAAGGCCGAA	AAAGCUU
2979	GGCAGUU	CUGAUGAGGCCGAAAGGCCGAA	AGAAAGC

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Table 5

Mouse ICAM HH Ribozyme Sequence  
nt. Position                      Ribozyme Sequence

11	CAACGGU	CUGAUGAGGCCGAAAGGCCGAA	ACCAGGG
23	AGCAGAG	CUGAUGAGGCCGAAAGGCCGAA	ACCACTG
26	AGGAGCA	CUGAUGAGGCCGAAAGGCCGAA	AGAACCA
31	UGGCGAG	CUGAUGAGGCCGAAAGGCCGAA	AGCAGAG
34	CGACCTU	CUGAUGAGGCCGAAAGGCCGAA	AUGAGAA
40	AGGCTAC	CUGAUGAGGCCGAAAGGCCGAA	AGUGUGC
48	CCAGGCU	CUGAUGAGGCCGAAAGGCCGAA	AGGUCCU
54	CCAUCAC	CUGAUGAGGCCGAAAGGCCGAA	AGGCCCA
58	GGAGCTA	CUGAUGAGGCCGAAAGGCCGAA	AGGCAUG
64	CUGCUGG	CUGAUGAGGCCGAAAGGCCGAA	AGGGGUG
96	GGGCCAG	CUGAUGAGGCCGAAAGGCCGAA	AGCAGAG
102	CCAGCAG	CUGAUGAGGCCGAAAGGCCGAA	ACTUGCA
108	GGGCCAG	CUGAUGAGGCCGAAAGGCCGAA	AGCAGAG
115	AGGAGCA	CUGAUGAGGCCGAAAGGCCGAA	AGAACCA
119	UCCUGGU	CUGAUGAGGCCGAAAGGCCGAA	ACAUCC
120	GGGCCAG	CUGAUGAGGCCGAAAGGCCGAA	AGCAGAG
146	GGAAGCG	CUGAUGAGGCCGAAAGGCCGAA	ACGACTG
152	AGUGGCU	CUGAUGAGGCCGAAAGGCCGAA	ACACAGA
158	GGUUUUU	CUGAUGAGGCCGAAAGGCCGAA	AACAGCA
165	GCAAAAC	CUGAUGAGGCCGAAAGGCCGAA	ACUUCUG
168	GGGGCAG	CUGAUGAGGCCGAAAGGCCGAA	AAGGCTU
185	CUGCACG	CUGAUGAGGCCGAAAGGCCGAA	ACCCACC
209	GCCAGAG	CUGAUGAGGCCGAAAGGCCGAA	AAGUGGC
227	GCAAAAC	CUGAUGAGGCCGAAAGGCCGAA	ACUUCUG
230	GGAGCAA	CUGAUGAGGCCGAAAGGCCGAA	ACTACTU
237	AGUUCUC	CUGAUGAGGCCGAAAGGCCGAA	AAGCACA
248	UUUAGGA	CUGAUGAGGCCGAAAGGCCGAA	AUGGGUU
253	UCCUCCU	CUGAUGAGGCCGAAAGGCCGAA	AGGCAGG
263	CAGUAGA	CUGAUGAGGCCGAAAGGCCGAA	AAACCCU
267	UAGGCAG	CUGAUGAGGCCGAAAGGCCGAA	AGCCCTU
293	CAGCUCA	CUGAUGAGGCCGAAAGGCCGAA	ACAGCTU
319	GGCUCAG	CUGAUGAGGCCGAAAGGCCGAA	AUCUCCU
335	GUUCUCA	CUGAUGAGGCCGAAAGGCCGAA	AGCACAG
337	CAGUGUG	CUGAUGAGGCCGAAAGGCCGAA	AUUGGAC
338	UCAGCUC	CUGAUGAGGCCGAAAGGCCGAA	AACAGCTU
359	AGCGGAC	CUGAUGAGGCCGAAAGGCCGAA	ACUGCAC
367	CGGGUUG	CUGAUGAGGCCGAAAGGCCGAA	AGCCAUU
374	GGGCAGG	CUGAUGAGGCCGAAAGGCCGAA	AGGCUUC
375	GGGGCAG	CUGAUGAGGCCGAAAGGCCGAA	AAGGCTU
378	ACAAGGU	CUGAUGAGGCCGAAAGGCCGAA	AUGGUAG
386	AAACGAA	CUGAUGAGGCCGAAAGGCCGAA	ACACGGU
394	AGAUCGA	CUGAUGAGGCCGAAAGGCCGAA	AGUCCGG
420	CGGGGGG	CUGAUGAGGCCGAAAGGCCGAA	AAGUGUG
425	CUGCUGG	CUGAUGAGGCCGAAAGGCCGAA	AGGGGUG

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427	CACUGCU	CUGAUGAGGCCGAAAGGCCGAA	AGAGCUG
450	GCAGGGU	CUGAUGAGGCCGAAAGGCCGAA	AGGUCCU
451	CAAAGGA	CUGAUGAGGCCGAAAGGCCGAA	AGGUUUC
456	AGUGGCU	CUGAUGAGGCCGAAAGGCCGAA	AGSGUAA
495	ACACGGU	CUGAUGAGGCCGAAAGGCCGAA	AUGGUAG
510	CCCCACG	CUGAUGAGGCCGAAAGGCCGAA	AGCAGCA
564	GGAUUGA	CUGAUGAGGCCGAAAGGCCGAA	ACCUAGG
592	CCCAUGU	CUGAUGAGGCCGAAAGGCCGAA	AUCUUUC
607	CAUGAGA	CUGAUGAGGCCGAAAGGCCGAA	AUUGGCU
608	GCAUGAG	CUGAUGAGGCCGAAAGGCCGAA	AAUUGGC
609	GGCAUGA	CUGAUGAGGCCGAAAGGCCGAA	AAAUUGG
611	CGGCGAU	CUGAUGAGGCCGAAAGGCCGAA	AGAAAUU
656	CAGCUCA	CUGAUGAGGCCGAAAGGCCGAA	ACAGCUU
657	UCAGCUC	CUGAUGAGGCCGAAAGGCCGAA	AACAGCU
668	GGUGGCC	CUGAUGAGGCCGAAAGGCCGAA	AGGCUUG
677	AGGCUGG	CUGAUGAGGCCGAAAGGCCGAA	AGAGGUC
684	AGGACCG	CUGAUGAGGCCGAAAGGCCGAA	AGCUGAA
692	AAGAUCG	CUGAUGAGGCCGAAAGGCCGAA	AAGUCCG
693	GCAGGGU	CUGAUGAGGCCGAAAGGCCGAA	AGGUCCU
696	GAGGCAG	CUGAUGAGGCCGAAAGGCCGAA	AAACAGG
709	UGAGGUG	CUGAUGAGGCCGAAAGGCCGAA	AGCGGCC
720	AGCUGAA	CUGAUGAGGCCGAAAGGCCGAA	AGUUGUA
723	CGGAGCU	CUGAUGAGGCCGAAAGGCCGAA	AAAAGUU
735	UCUCCAG	CUGAUGAGGCCGAAAGGCCGAA	AUCUGGU
738	CCAUCAC	CUGAUGAGGCCGAAAGGCCGAA	AGSCCCA
765	GGAAAGC	CUGAUGAGGCCGAAAGGCCGAA	ACGACUG
769	GGCAGGA	CUGAUGAGGCCGAAAGGCCGAA	ACAGGCC
770	UUC CAGG	CUGAUGAGGCCGAAAGGCCGAA	AGCAAAA
785	GGCAGGA	CUGAUGAGGCCGAAAGGCCGAA	ACAGGCC
786	AGGCAGG	CUGAUGAGGCCGAAAGGCCGAA	AACAGGC
792	CUUCCGA	CUGAUGAGGCCGAAAGGCCGAA	ACCUCCA
794	AGUCUCC	CUGAUGAGGCCGAAAGGCCGAA	AGCCAGG
807	CCAGGUA	CUGAUGAGGCCGAAAGGCCGAA	AUCCGAG
833	GGGUGUC	CUGAUGAGGCCGAAAGGCCGAA	AGCUUUG
846	CAAAGGU	CUGAUGAGGCCGAAAGGCCGAA	ACCAGGG
851	GCTGGUA	CUGAUGAGGCCGAAAGGCCGAA	AGGUCUC
863	CCAGAGG	CUGAUGAGGCCGAAAGGCCGAA	AGUGGCU
866	GGGCAGG	CUGAUGAGGCCGAAAGGCCGAA	AGGCUUC
867	UCUCCGG	CUGAUGAGGCCGAAAGGCCGAA	AACGAUU
869	CUUGCAU	CUGAUGAGGCCGAAAGGCCGAA	AGGAAGA
881	ACGGGUU	CUGAUGAGGCCGAAAGGCCGAA	AAGCCAU
885	UCACCTUC	CUGAUGAGGCCGAAAGGCCGAA	ACCAAGG
933	CCAGAAU	CUGAUGAGGCCGAAAGGCCGAA	AUUAUAG
936	GCAC CAG	CUGAUGAGGCCGAAAGGCCGAA	AUGADUA
978	AGUUGUA	CUGAUGAGGCCGAAAGGCCGAA	ACUGUUA
980	AAAGUUG	CUGAUGAGGCCGAAAGGCCGAA	AGACUGU
986	AGCUGAA	CUGAUGAGGCCGAAAGGCCGAA	AGUUGUA
987	GAGCUGA	CUGAUGAGGCCGAAAGGCCGAA	AAGUUGU
988	GGAGCTUG	CUGAUGAGGCCGAAAGGCCGAA	AAAGUUG

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1005	UCUCCAG	CUGAUGAGGCCGAAAGGCCGAA	AUCUGGU
1006	UUCCCCA	CUGAUGAGGCCGAAAGGCCGAA	ACUCUCA
1023	CUUCCGA	CUGAUGAGGCCGAAAGGCCGAA	ACCUCCA
1025	CCCUUCC	CUGAUGAGGCCGAAAGGCCGAA	AGACUUC
1066	UUUUUUU	CUGAUGAGGCCGAAAGGCCGAA	AGAGUGG
1092	GGCCUGA	CUGAUGAGGCCGAAAGGCCGAA	AUCCAGU
1093	UUGGCUG	CUGAUGAGGCCGAAAGGCCGAA	AGGUCCA
1125	UCAAGAA	CUGAUGAGGCCGAAAGGCCGAA	AGUUGGG
1163	GCAAAAG	CUGAUGAGGCCGAAAGGCCGAA	AGCUUCC
1164	AGCAAAA	CUGAUGAGGCCGAAAGGCCGAA	AAGCUUC
1166	AGAGCAA	CUGAUGAGGCCGAAAGGCCGAA	AGAAGCU
1172	GGUUUUU	CUGAUGAGGCCGAAAGGCCGAA	AACAGGA
1200	UGGGGAG	CUGAUGAGGCCGAAAGGCCGAA	AGCAGAG
1201	CUGUCCA	CUGAUGAGGCCGAAAGGCCGAA	AAGCAGC
1203	ACUGGUG	CUGAUGAGGCCGAAAGGCCGAA	AAAAAGU
1227	GCACACG	CUGAUGAGGCCGAAAGGCCGAA	AUGUACC
1228	AGCAAAA	CUGAUGAGGCCGAAAGGCCGAA	AAGCUUC
1233	CUUCCCG	CUGAUGAGGCCGAAAGGCCGAA	AAACGAA
1238	AGGACCA	CUGAUGAGGCCGAAAGGCCGAA	ACAGCAC
1264	CUUGCAC	CUGAUGAGGCCGAAAGGCCGAA	ACCCUUC
1267	UUCCCCA	CUGAUGAGGCCGAAAGGCCGAA	ACUCUCA
1294	GGCUCAG	CUGAUGAGGCCGAAAGGCCGAA	AUCUCCU
1295	CUGCUGA	CUGAUGAGGCCGAAAGGCCGAA	ACCCUUC
1306	CAUUUCA	CUGAUGAGGCCGAAAGGCCGAA	AGUCUGC
1321	UCCUCCU	CUGAUGAGGCCGAAAGGCCGAA	AGCCUUC
1334	UUUAGGA	CUGAUGAGGCCGAAAGGCCGAA	AUGGCUU
1344	CACUCUC	CUGAUGAGGCCGAAAGGCCGAA	AGCUCAU
1351	UAAUUUA	CUGAUGAGGCCGAAAGGCCGAA	ACAUUCA
1353	CACCUUC	CUGAUGAGGCCGAAAGGCCGAA	ACCCACU
1366	AGUUGUA	CUGAUGAGGCCGAAAGGCCGAA	ACUGUUA
1367	AGGUGGG	CUGAUGAGGCCGAAAGGCCGAA	AGGUGCU
1368	AGAGUGG	CUGAUGAGGCCGAAAGGCCGAA	ACAGUAC
1380	CCACCCC	CUGAUGAGGCCGAAAGGCCGAA	AUGGGCA
1388	AGCCACTU	CUGAUGAGGCCGAAAGGCCGAA	AGUCUCC
1398	GUUCUGU	CUGAUGAGGCCGAAAGGCCGAA	ACAGCCA
1402	AGUUCUC	CUGAUGAGGCCGAAAGGCCGAA	AAGCACA
1408	CCUCCCC	CUGAUGAGGCCGAAAGGCCGAA	AUCUCCG
1410	CCCUUCC	CUGAUGAGGCCGAAAGGCCGAA	AGACUUC
1421	ACAAAAG	CUGAUGAGGCCGAAAGGCCGAA	AGGUGGG
1425	CUCUACC	CUGAUGAGGCCGAAAGGCCGAA	AGGCAGU
1429	CAGGGGC	CUGAUGAGGCCGAAAGGCCGAA	AUAGAGA
1444	UCCUCCU	CUGAUGAGGCCGAAAGGCCGAA	AGCCUUC
1455	UCCUGGU	CUGAUGAGGCCGAAAGGCCGAA	ACAUUCU
1482	GGGAGCA	CUGAUGAGGCCGAAAGGCCGAA	AACAACU
1484	CAUGAGG	CUGAUGAGGCCGAAAGGCCGAA	AGAACAG
1493	GUUCUCA	CUGAUGAGGCCGAAAGGCCGAA	AGCACAG
1500	GGACCAU	CUGAUGAGGCCGAAAGGCCGAA	AUUUCAU
1503	GAUUGAU	CUGAUGAGGCCGAAAGGCCGAA	AUAGUCC
1506	CGGUUUA	CUGAUGAGGCCGAAAGGCCGAA	AACAUAA

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1509	ACA CGU	CUGAUGAGGCCGAAAGGCCGAA	AUGGUAG
1518	CGCCUGG	CUGAUGAGGCCGAAAGGCCGAA	ACCAUGA
1530	CCAGAAU	CUGAUGAGGCCGAAAGGCCGAA	AUUADAG
1533	GGCCAC	CUGAUGAGGCCGAAAGGCCGAA	AUGACCA
1551	AGCUGCU	CUGAUGAGGCCGAAAGGCCGAA	AGGCAUG
1559	AGGUGGG	CUGAUGAGGCCGAAAGGCCGAA	AGGUGCU
1563	GGUUAUA	CUGAUGAGGCCGAAAGGCCGAA	ACAUAAG
1565	GCGGUUA	CUGAUGAGGCCGAAAGGCCGAA	AAACAUA
1567	UGGCGGU	CUGAUGAGGCCGAAAGGCCGAA	AUAACA
1584	AUAUCCU	CUGAUGAGGCCGAAAGGCCGAA	AUCUUC
1592	UAACUUG	CUGAUGAGGCCGAAAGGCCGAA	AUAUCCU
1599	CCUUCUG	CUGAUGAGGCCGAAAGGCCGAA	AACUUGU
1651	GCUCAGG	CUGAUGAGGCCGAAAGGCCGAA	AGGUGGG
1661	CAAGGA	CUGAUGAGGCCGAAAGGCCGAA	AGGUUUC
1663	UUCAAAG	CUGAUGAGGCCGAAAGGCCGAA	AAAGGUU
1678	CCAGGCU	CUGAUGAGGCCGAAAGGCCGAA	AGGUCCU
1680	CCAGAGG	CUGAUGAGGCCGAAAGGCCGAA	AGUGGCU
1681	GCCAGAG	CUGAUGAGGCCGAAAGGCCGAA	AAGUGGC
1684	ACAGCCA	CUGAUGAGGCCGAAAGGCCGAA	AGGAAGU
1690	AGAUCCA	CUGAUGAGGCCGAAAGGCCGAA	AGUCCCG
1691	AAGAUCG	CUGAUGAGGCCGAAAGGCCGAA	AAGUCCG
1696	CCACCCG	CUGAUGAGGCCGAAAGGCCGAA	AUGGGCA
1698	CCCCAGG	CUGAUGAGGCCGAAAGGCCGAA	AUAUCCG
1737	GCUGGUA	CUGAUGAGGCCGAAAGGCCGAA	AGGUCCG
1750	UGAGGUG	CUGAUGAGGCCGAAAGGCCGAA	AGCCGCC
1756	GGGCAGG	CUGAUGAGGCCGAAAGGCCGAA	AGGCUUC
1787	UGGGGAC	CUGAUGAGGCCGAAAGGCCGAA	AUGUCUC
1790	AUUAAGG	CUGAUGAGGCCGAAAGGCCGAA	ACAADGC
1793	UCCAGCC	CUGAUGAGGCCGAAAGGCCGAA	AGGACCA
1797	UUUAUGU	CUGAUGAGGCCGAAAGGCCGAA	ACUGGUG
1802	UCUCCAG	CUGAUGAGGCCGAAAGGCCGAA	AUCGGGU
1812	GGCCUGA	CUGAUGAGGCCGAAAGGCCGAA	AUCCAGU
1813	UGAGGGU	CUGAUGAGGCCGAAAGGCCGAA	AAGGCUG
1825	GCAGAGG	CUGAUGAGGCCGAAAGGCCGAA	AGCGUGG
1837	GGAGCUA	CUGAUGAGGCCGAAAGGCCGAA	AGGCAUG
1845	GGUGGCC	CUGAUGAGGCCGAAAGGCCGAA	AGGCUCC
1856	AAGAUCG	CUGAUGAGGCCGAAAGGCCGAA	AAGUCCG
1861	UACUGGA	CUGAUGAGGCCGAAAGGCCGAA	AUCADGU
1865	CUGAGGC	CUGAUGAGGCCGAAAGGCCGAA	ACAAGUG
1868	UUUAUGU	CUGAUGAGGCCGAAAGGCCGAA	ACUGGUG
1877	AGCUGCU	CUGAUGAGGCCGAAAGGCCGAA	AGGCAUG
1901	GUCCCUU	CUGAUGAGGCCGAAAGGCCGAA	AGUUUUA
1912	ACUGAUC	CUGAUGAGGCCGAAAGGCCGAA	ACTUAUA
1922	UAACUUA	CUGAUGAGGCCGAAAGGCCGAA	ACAUAUA
1923	GAUAUCC	CUGAUGAGGCCGAAAGGCCGAA	AGCAUCA
1928	CUGGUAA	CUGAUGAGGCCGAAAGGCCGAA	ACUCUAA
1930	AGCUGGU	CUGAUGAGGCCGAAAGGCCGAA	AAACUCU
1964	UGGGGAC	CUGAUGAGGCCGAAAGGCCGAA	AUGUCUC
1983	UAACUUG	CUGAUGAGGCCGAAAGGCCGAA	AUAUCCU

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1996	GGCUCAG	CUGAUGAGGCCGAAAGGCCGAA	ADCUCU
2005	GGUCCGC	CUGAUGAGGCCGAAAGGCCGAA	AGCUCCA
2013	UACUCAA	CUGAUGAGGCCGAAAGGCCGAA	AAAUAGC
2015	CCACCCC	CUGAUGAGGCCGAAAGGCCGAA	AUGGGCA
2020	CUCAGAA	CUGAUGAGGCCGAAAGGCCGAA	AACCACC
2039	CCUCUGC	CUGAUGAGGCCGAAAGGCCGAA	AGCCAGC
2040	CCUCCAG	CUGAUGAGGCCGAAAGGCCGAA	AGGUCAG
2057	GGAUGUG	CUGAUGAGGCCGAAAGGCCGAA	AGGAGCA
2061	ACACGGU	CUGAUGAGGCCGAAAGGCCGAA	AUGGUAG
2071	CUGAGGC	CUGAUGAGGCCGAAAGGCCGAA	ACAAGUG
2076	UAGCUCU	CUGAUGAGGCCGAAAGGCCGAA	AGGCUAC
2097	CAUCAAG	CUGAUGAGGCCGAAAGGCCGAA	AGAGUUG
2098	CGGGGGG	CUGAUGAGGCCGAAAGGCCGAA	AAGUGUG
2115	AUCCUCC	CUGAUGAGGCCGAAAGGCCGAA	AGCUGGC
2128	CUCAUA	CUGAUGAGGCCGAAAGGCCGAA	AUAGCUG
2130	GAGGCAG	CUGAUGAGGCCGAAAGGCCGAA	AAACAGG
2145	CAUCAAG	CUGAUGAGGCCGAAAGGCCGAA	AGAGUUG
2152	AACUCUA	CUGAUGAGGCCGAAAGGCCGAA	AUUAUA
2156	UAADAAA	CUGAUGAGGCCGAAAGGCCGAA	ACAUCAA
2158	AUUAUA	CUGAUGAGGCCGAAAGGCCGAA	AUACAUC
2159	AAUUAU	CUGAUGAGGCCGAAAGGCCGAA	AAUACAU
2160	AAAUUA	CUGAUGAGGCCGAAAGGCCGAA	AAAUACA
2162	CUAAAU	CUGAUGAGGCCGAAAGGCCGAA	AUAAUA
2163	AAUUAU	CUGAUGAGGCCGAAAGGCCGAA	AAUACAU
2166	AAUAGAG	CUGAUGAGGCCGAAAGGCCGAA	AUGAAGU
2167	AAUUAU	CUGAUGAGGCCGAAAGGCCGAA	AAUACAU
2170	CUAAAU	CUGAUGAGGCCGAAAGGCCGAA	AUAAUA
2171	GGGAGCA	CUGAUGAGGCCGAAAGGCCGAA	AACAACU
2173	CUGGUA	CUGAUGAGGCCGAAAGGCCGAA	ACUCUAA
2174	GCUGGUA	CUGAUGAGGCCGAAAGGCCGAA	AACUCUA
2175	AGCUGGU	CUGAUGAGGCCGAAAGGCCGAA	AAACUCU
2176	UAGCUGG	CUGAUGAGGCCGAAAGGCCGAA	AAAACUC
2183	CAAUAA	CUGAUGAGGCCGAAAGGCCGAA	AGCUGGU
2185	CUCAUA	CUGAUGAGGCCGAAAGGCCGAA	AUAGCUG
2186	ACUCAU	CUGAUGAGGCCGAAAGGCCGAA	AUAGCU
2187	UACUCA	CUGAUGAGGCCGAAAGGCCGAA	AAAUAGC
2189	GGUACUC	CUGAUGAGGCCGAAAGGCCGAA	AUAAUA
2196	CAUCAAG	CUGAUGAGGCCGAAAGGCCGAA	AGAGUUG
2198	AACAUA	CUGAUGAGGCCGAAAGGCCGAA	AGGCUGC
2199	AUAAACA	CUGAUGAGGCCGAAAGGCCGAA	AAGAGGC
2200	CUUGCAU	CUGAUGAGGCCGAAAGGCCGAA	AGGAAGA
2201	GCCGACA	CUGAUGAGGCCGAAAGGCCGAA	AAAACUU
2205	UCAGGCC	CUGAUGAGGCCGAAAGGCCGAA	ACAUAAA
2210	AGCCACT	CUGAUGAGGCCGAAAGGCCGAA	AGUCUCC
2220	AGAGAAC	CUGAUGAGGCCGAAAGGCCGAA	AUGCCAG
2224	GGAGGA	CUGAUGAGGCCGAAAGGCCGAA	ACCUAGG
2226	GCGGCCU	CUGAUGAGGCCGAAAGGCCGAA	AGAUGCA
2233	CCUCCAG	CUGAUGAGGCCGAAAGGCCGAA	AGGUCAG
2242	GGUCCGC	CUGAUGAGGCCGAAAGGCCGAA	AGCUCCA

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2248	UGGGAUG	CUGAUGAGGCCGAAAGGCCGAA	AUGGAUA
2254	UCAGUGU	CUGAUGAGGCCGAAAGGCCGAA	AAUUGGA
2259	CACCGUG	CUGAUGAGGCCGAAAGGCCGAA	AUGUGAU
2260	GCACCGU	CUGAUGAGGCCGAAAGGCCGAA	AAUGUGA
2266	UCCUGGU	CUGAUGAGGCCGAAAGGCCGAA	ACAUUCC
2274	UCUCCAG	CUGAUGAGGCCGAAAGGCCGAA	AUCUGGU
2279	CUUGCAC	CUGAUGAGGCCGAAAGGCCGAA	ACCCUUC
2282	CAGCUCA	CUGAUGAGGCCGAAAGGCCGAA	ACAGCUU
2288	AGGCCAU	CUGAUGAGGCCGAAAGGCCGAA	ACUUAUA
2291	AGCAGAG	CUGAUGAGGCCGAAAGGCCGAA	ACCACUG
2321	CCCADGU	CUGAUGAGGCCGAAAGGCCGAA	AUCUUUC
2338	CAGGCAG	CUGAUGAGGCCGAAAGGCCGAA	AGUCUCA
2339	CAAAGGA	CUGAUGAGGCCGAAAGGCCGAA	AGGUUUC
2341	AGGCUUG	CUGAUGAGGCCGAAAGGCCGAA	AGAGGUC
2344	GCUGGAA	CUGAUGAGGCCGAAAGGCCGAA	AUCGAAA
2358	CUGCUGA	CUGAUGAGGCCGAAAGGCCGAA	AGCUGGG
2359	UCUGUUC	CUGAUGAGGCCGAAAGGCCGAA	AAAGCAG
2360	UUCAAAG	CUGAUGAGGCCGAAAGGCCGAA	AAAGGUU
2376	UCAGAAG	CUGAUGAGGCCGAAAGGCCGAA	ACCACCU
2377	UCACAGAA	CUGAUGAGGCCGAAAGGCCGAA	AACCACC
2378	CAGUAGA	CUGAUGAGGCCGAAAGGCCGAA	AAACCCU
2379	CUUAUGA	CUGAUGAGGCCGAAAGGCCGAA	AAAAGCA
2380	GCCGACA	CUGAUGAGGCCGAAAGGCCGAA	AAAACUU
2382	GGGGCAA	CUGAUGAGGCCGAAAGGCCGAA	AGAGAAU
2384	UUGUGUC	CUGAUGAGGCCGAAAGGCCGAA	ACUGGAU
2399	GUCCACA	CUGAUGAGGCCGAAAGGCCGAA	AGUGUUU
2401	CAGCUCA	CUGAUGAGGCCGAAAGGCCGAA	ACAGCUU
2411	GCAUCCU	CUGAUGAGGCCGAAAGGCCGAA	ACCAGUA
2417	ACGUUUG	CUGAUGAGGCCGAAAGGCCGAA	ACCAUUC
2418	GGCCUGA	CUGAUGAGGCCGAAAGGCCGAA	AUCCAGU
2425	AACCCTC	CUGAUGAGGCCGAAAGGCCGAA	ACCCAUG
2426	AAACUCU	CUGAUGAGGCCGAAAGGCCGAA	AAUUAUU
2433	GCUGGUA	CUGAUGAGGCCGAAAGGCCGAA	AACUCUA
2434	AGCUGGU	CUGAUGAGGCCGAAAGGCCGAA	AAACUCU
2448	GGGCAGG	CUGAUGAGGCCGAAAGGCCGAA	AGGCUUC
2449	GGGSCAG	CUGAUGAGGCCGAAAGGCCGAA	AAGGCUU
2451	AGGCAGG	CUGAUGAGGCCGAAAGGCCGAA	AACAGGC
2452	GAGGCAG	CUGAUGAGGCCGAAAGGCCGAA	AAACAGG
2455	GGGCAGG	CUGAUGAGGCCGAAAGGCCGAA	AGGCUUC
2459	GGGGGGG	CUGAUGAGGCCGAAAGGCCGAA	AGUGUGG
2460	CGGGGGG	CUGAUGAGGCCGAAAGGCCGAA	AAGUGUG
2479	GCUGGUA	CUGAUGAGGCCGAAAGGCCGAA	AGGUUCU
2480	GAUUCAC	CUGAUGAGGCCGAAAGGCCGAA	ACGGUGA
2483	GGUGGCU	CUGAUGAGGCCGAAAGGCCGAA	ACAUUGG
2484	GACUGGU	CUGAUGAGGCCGAAAGGCCGAA	AAAAAAG
2492	AGGUGGG	CUGAUGAGGCCGAAAGGCCGAA	AGGUGCU
2504	ACAAAAG	CUGAUGAGGCCGAAAGGCCGAA	AGGUGGG
2508	UGGGAUG	CUGAUGAGGCCGAAAGGCCGAA	AUGGAUA
2509	CUGGUAU	CUGAUGAGGCCGAAAGGCCGAA	ACUCUAA

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2510	GCUGGUA	CUGAUGAGGCCGAAAGGCCGAA	AACUCUA
2520	CAUUGGG	CUGAUGAGGCCGAAAGGCCGAA	ACAAAAG
2521	UGAGGGU	CUGAUGAGGCCGAAAGGCCGAA	AADGCTG
2533	GAUACCU	CUGAUGAGGCCGAAAGGCCGAA	AGCAUCA
2540	CACAGCG	CUGAUGAGGCCGAAAGGCCGAA	ACTGCTG
2545	AGGACCA	CUGAUGAGGCCGAAAGGCCGAA	ACAGCAC
2568	UUUGACA	CUGAUGAGGCCGAAAGGCCGAA	ACTUCAC
2579	CAGGCCA	CUGAUGAGGCCGAAAGGCCGAA	AACUUAU
2585	AGAGAAC	CUGAUGAGGCCGAAAGGCCGAA	AUGCCAG
2588	AUUAGAG	CUGAUGAGGCCGAAAGGCCGAA	ACAAUGC
2591	AGGAGCA	CUGAUGAGGCCGAAAGGCCGAA	AGAACCA
2593	GCAGAGC	CUGAUGAGGCCGAAAGGCCGAA	AAAGAAG
2596	CAUUGGG	CUGAUGAGGCCGAAAGGCCGAA	ACAAAAG
2601	AAACGAA	CUGAUGAGGCCGAAAGGCCGAA	ACACGGU
2602	GGGAUUG	CUGAUGAGGCCGAAAGGCCGAA	AGCTUGA
2607	CCAGGUA	CUGAUGAGGCCGAAAGGCCGAA	AUCCGAG
2608	CACAGCG	CUGAUGAGGCCGAAAGGCCGAA	ACTGCTG
2609	UCCUGGU	CUGAUGAGGCCGAAAGGCCGAA	ACAUCC
2620	GCAGGGU	CUGAUGAGGCCGAAAGGCCGAA	AGGUCCU
2626	GCUGGAA	CUGAUGAGGCCGAAAGGCCGAA	AUCGAAA
2628	AGGCUAC	CUGAUGAGGCCGAAAGGCCGAA	AGUGUGC
2635	AGGAOCG	CUGAUGAGGCCGAAAGGCCGAA	AGCUGAA
2640	GGCAGGA	CUGAUGAGGCCGAAAGGCCGAA	ACAGGCC
2641	CUGCTGA	CUGAUGAGGCCGAAAGGCCGAA	AGCTUGG
2642	GAGGCAG	CUGAUGAGGCCGAAAGGCCGAA	AAACAGG
2653	GCAUCCU	CUGAUGAGGCCGAAAGGCCGAA	ACCAGUA
2659	CUUGCAC	CUGAUGAGGCCGAAAGGCCGAA	ACCCUUC
2689	CCUCGGA	CUGAUGAGGCCGAAAGGCCGAA	ACAUUAG
2691	GGCCUCG	CUGAUGAGGCCGAAAGGCCGAA	AGACAUU
2700	GGGCAGG	CUGAUGAGGCCGAAAGGCCGAA	AGGCUUC
2704	AGGCTUG	CUGAUGAGGCCGAAAGGCCGAA	AGAGGUC
2711	CUGCTGA	CUGAUGAGGCCGAAAGGCCGAA	AGCTUGG
2712	CCCUUCC	CUGAUGAGGCCGAAAGGCCGAA	AGACCTC
2721	CUUGCAC	CUGAUGAGGCCGAAAGGCCGAA	ACCCUUC
2724	GCACACG	CUGAUGAGGCCGAAAGGCCGAA	AUUAACC
2744	CUGCACG	CUGAUGAGGCCGAAAGGCCGAA	ACCCACC
2750	GGUACUC	CUGAUGAGGCCGAAAGGCCGAA	AUAAAUA
2759	AGAUCGA	CUGAUGAGGCCGAAAGGCCGAA	AGUCCGG
2761	GCAGGGU	CUGAUGAGGCCGAAAGGCCGAA	AGGUCCU
2765	AGCGGCA	CUGAUGAGGCCGAAAGGCCGAA	AGCAAAA
2769	CCUGUUU	CUGAUGAGGCCGAAAGGCCGAA	ACAGACU
2797	GGACCAU	CUGAUGAGGCCGAAAGGCCGAA	AUUUCAU
2803	CGCCUGG	CUGAUGAGGCCGAAAGGCCGAA	ACCAUGA
2804	CUGCACG	CUGAUGAGGCCGAAAGGCCGAA	ACCCACC
2813	GGGUCAG	CUGAUGAGGCCGAAAGGCCGAA	ACCGGAG
2815	AAAGUUG	CUGAUGAGGCCGAAAGGCCGAA	AGACUGU
2821	CCUCCAG	CUGAUGAGGCCGAAAGGCCGAA	AGGUCAG
2822	AAGUCCG	CUGAUGAGGCCGAAAGGCCGAA	AGGCUCC
2823	UGGGAGC	CUGAUGAGGCCGAAAGGCCGAA	AAAGGCA

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2829	AUGAUUA	CUGAUGAGGCCGAAAGGCCGAA	AGUCCAG
2837	UCAGAAG	CUGAUGAGGCCGAAAGGCCGAA	ACCACCTU
2840	CAGGCAG	CUGAUGAGGCCGAAAGGCCGAA	AGUCUCA
2847	GGUGGCTU	CUGAUGAGGCCGAAAGGCCGAA	ACAUUGG
2853	AACAUA	CUGAUGAGGCCGAAAGGCCGAA	AGGCTGC
2860	UCACAGU	CUGAUGAGGCCGAAAGGCCGAA	ACUUGGC
2872	CUUGGCTU	CUGAUGAGGCCGAAAGGCCGAA	AAGGUCC
2877	GUGAUGG	CUGAUGAGGCCGAAAGGCCGAA	AGCGSAA
2899	AAGAUCG	CUGAUGAGGCCGAAAGGCCGAA	AAGUCCG
2900	AAAACUC	CUGAUGAGGCCGAAAGGCCGAA	AAAUUA
2904	AAUAGAG	CUGAUGAGGCCGAAAGGCCGAA	AUGAAGU
2905	CAAUAGA	CUGAUGAGGCCGAAAGGCCGAA	AAUGAAG
2906	UAAUAAA	CUGAUGAGGCCGAAAGGCCGAA	ACAUCAA
2907	AAAUUAA	CUGAUGAGGCCGAAAGGCCGAA	AAAUACA
2908	AGCAAAA	CUGAUGAGGCCGAAAGGCCGAA	AAGCUUC
2909	AGAGCAA	CUGAUGAGGCCGAAAGGCCGAA	AGAAGCU
2910	AAAUUAA	CUGAUGAGGCCGAAAGGCCGAA	AAAUACA
2911	AAAUUAA	CUGAUGAGGCCGAAAGGCCGAA	AAAUACA
2912	GACAUUA	CUGAUGAGGCCGAAAGGCCGAA	AGAACAA
2913	UGACCAG	CUGAUGAGGCCGAAAGGCCGAA	AGAGAAA
2914	CUUAUGA	CUGAUGAGGCCGAAAGGCCGAA	AAAAGCA
2915	UCUAAAU	CUGAUGAGGCCGAAAGGCCGAA	AAUAAAU
2916	CUCGCGA	CUGAUGAGGCCGAAAGGCCGAA	ACGAUUA
2917	UCUCCGG	CUGAUGAGGCCGAAAGGCCGAA	AACGAUU
2918	CUCUCCG	CUGAUGAGGCCGAAAGGCCGAA	AAACGAA
2919	CGACCCU	CUGAUGAGGCCGAAAGGCCGAA	AUGAGAA
2931	CUUCCGA	CUGAUGAGGCCGAAAGGCCGAA	ACCUCCA
2933	CCCUUCC	CUGAUGAGGCCGAAAGGCCGAA	AGACCTC
2941	UGGGGAC	CUGAUGAGGCCGAAAGGCCGAA	AUGUCTC
2951	GCAGAGG	CUGAUGAGGCCGAAAGGCCGAA	AGCGGGG
2952	CACAGCG	CUGAUGAGGCCGAAAGGCCGAA	ACUGCTG
2955	UGACACA	CUGAUGAGGCCGAAAGGCCGAA	AGUCACU
2956	UUGAUUC	CUGAUGAGGCCGAAAGGCCGAA	AAGGAAA
2961	AGUGGCTU	CUGAUGAGGCCGAAAGGCCGAA	ACACAGA
2962	AAUUAUU	CUGAUGAGGCCGAAAGGCCGAA	AAUACAU
2965	CUUUAUU	CUGAUGAGGCCGAAAGGCCGAA	AUUCAAA
2966	CCUCUGC	CUGAUGAGGCCGAAAGGCCGAA	AGCCAGC
2969	AAAACUU	CUGAUGAGGCCGAAAGGCCGAA	AUUGAUU
2975	GCUGGUA	CUGAUGAGGCCGAAAGGCCGAA	AACUUA
2976	AGUAGAG	CUGAUGAGGCCGAAAGGCCGAA	AACCTUC
2977	CAGCUCA	CUGAUGAGGCCGAAAGGCCGAA	ACAGCTU
2979	GGCAUUA	CUGAUGAGGCCGAAAGGCCGAA	AGAAUGA

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Table 6  
Human ICAM Hairpin Ribozyme/Substrate Sequences

nt. Position	Hairpin Ribozyme Sequence	Substrate
70	GGGCGGG AGAA GCUG ACCAGAGAAACACACGUGUGUGUACAUUACCUUGGUA	CAGCA GCC CCGGCCCC
86	GGAGUGCG AGAA GCGC ACCAGAGAAACACACGUGUGUGUGUACAUUACCUUGGUA	GGCCU GCC CGCACUCC
343	CCCNUCAG AGAA GUUU ACCAGAGAAACACACGUGUGUGUGUACAUUACCUUGGUA	AAACU GCC CUGAUGGG
635	GCCUUGG AGAA GCAG ACCAGAGAAACACACGUGUGUGUGUACAUUACCUUGGUA	CUGCG GCC CCAAGGGC
655	UGUUCUCA AGAA GCUU ACCAGAGAAACACACGUGUGUGUGUACAUUACCUUGGUA	GAGCU GUU UGAGAAAC
782	AGACUGGG AGAA GCGC ACCAGAGAAACACACGUGUGUGUGUACAUUACCUUGGUA	GGCCU GUU CCGAGUCU
920	CUGCACAC AGAA GCGG ACCAGAGAAACACACGUGUGUGUGUACAUUACCUUGGUA	CGGCU GAC GUGUGCAG
1301	ACAUUGGA AGAA GCUU ACCAGAGAAACACACGUGUGUGUGUACAUUACCUUGGUA	CAGCA GAC UCCAAUGU
1373	CCCCGAUG AGAA GUGG ACCAGAGAAACACACGUGUGUGUGUACAUUACCUUGGUA	CCACU GCC CAUGGGGG
1521	AUGACUGC AGAA GCUA ACCAGAGAAACACACGUGUGUGUGUACAUUACCUUGGUA	UAGCA GCC GCAGUCAU
1594	CUGUGUA AGAA GUUU ACCAGAGAAACACACGUGUGUGUGUACAUUACCUUGGUA	AUACA GAC UACACACG
2008	ACCCAAUA AGAA GCAA ACCAGAGAAACACACGUGUGUGUGUACAUUACCUUGGUA	UUGCU GCC UAUUGGGU
2034	UUCUGUA AGAA GUGG ACCAGAGAAACACACGUGUGUGUGUACAUUACCUUGGUA	CCACA GAC UACACAGAA
2125	GGUCAGUA AGAA GCAG ACCAGAGAAACACACGUGUGUGUGUACAUUACCUUGGUA	CUGCU GUC UACUACCC
2132	GGGUGGG AGAA GUAG ACCAGAGAAACACACGUGUGUGUGUACAUUACCUUGGUA	CUACU GAC CCGACCCC
2276	ACCUGUAC AGAA GUAC ACCAGAGAAACACACGUGUGUGUGUACAUUACCUUGGUA	GUACA GUU GUACAGGU
2810	AAGGUCAA AGAA GCAG ACCAGAGAAACACACGUGUGUGUGUACAUUACCUUGGUA	CUGCA GUC UUGACCUU

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Table 7  
Mouse ICAM Hairpin Ribozyme/Substrate Sequences  
nt. Hairpin Ribozyme Sequence

Position	nt.	Substrate
76	GGGAUCAC AGAA GUGA ACCAGAGAAAACACACGUTUGUGGUACAUUACCUUGUA	UCACC GUU GUGAUCCC
164	UGAGGAAG AGAA GUUC ACCAGAGAAAACACACGUTUGUGGUACAUUACCUUGUA	GAACU GUU CUUCCUCA
252	UCAGTCUA AGAA GCUU ACCAGAGAAAACACACGUTUGUGGUACAUUACCUUGUA	AAGCU GUU UGAGCCUGA
284	GCACACCG AGAA GCTUG ACCAGAGAAAACACACGUTUGUGGUACAUUACCUUGUA	CAGCA GUC CGCUGUGC
318	AACGGGAC AGAA GCAC ACCAGAGAAAACACACGUTUGUGGUACAUUACCUUGUA	GUGCA GUC GUCCGCUU
447	AGAGCTUG AGAA GCGG ACCAGAGAAAACACACGUTUGUGGUACAUUACCUUGUA	CCGGG GAC CCAGCCUCU
804	UTUCCUGG AGAA GCAU ACCAGAGAAAACACACGUTUGUGGUACAUUACCUUGUA	AUGCC GAC CCAGGAGA
847	UTUACCAA AGAA GUGG ACCAGAGAAAACACACGUTUGUGGUACAUUACCUUGUA	CCACU GCC UUGGUAGA
913	AGGAUTUG AGAA GCUA ACCAGAGAAAACACACGUTUGUGGUACAUUACCUUGUA	UAGCG GAC CAGAUCCU
946	AAGUTUGA AGAA GUUA ACCAGAGAAAACACACGUTUGUGGUACAUUACCUUGUA	UAACA GUC UACGAACUU
1234	CCCAAGCA AGAA GUCU ACCAGAGAAAACACACGUTUGUGGUACAUUACCUUGUA	AGACG GAC UGGTUUGG
1275	AUUUCAGA AGAA GCTUG ACCAGAGAAAACACACGUTUGUGGUACAUUACCUUGUA	CAGCA GAC UCTUGAAU
1325	UGCCTUCC AGAA GCAG ACCAGAGAAAACACACGUTUGUGGUACAUUACCUUGUA	CUGCA GAC GGAAGGCA
1350	CCCCGAG AGAA GCAG ACCAGAGAAAACACACGUTUGUGGUACAUUACCUUGUA	CUGCU GCC CAUCCGGG
1534	ACAUAGA AGAA GCCA ACCAGAGAAAACACACGUTUGUGGUACAUUACCUUGUA	UAGCA GCC UCUUAUGU
1851	GUCCACCG AGAA GUAG ACCAGAGAAAACACACGUTUGUGGUACAUUACCUUGUA	CUACA GCC CGGUGGAC
1880	AGAAUGAA AGAA GCGU ACCAGAGAAAACACACGUTUGUGGUACAUUACCUUGUA	ACGCU GAC UUCAUUCU

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Table 8  
Rat ICAM Hairpin Ribozyme/Substrate Sequences

nt.	Hairpin Ribozyme Sequence	Substrate
Position		
5	AAAGUGCA AGAA GCAG ACCAGAGAAACACACGUGUGUGUA CAUUAUACCUUGUA	CUGCU GCC UGCACUUU
59	GGAGCAGA AGAA GCAU ACCAGAGAAACACACGUGUGUGUA CAUUAUACCUUGUA	AUGCU GCC UUGCUUCC
84	GGGAUCAC AGAA GCGA ACCAGAGAAACACACGUGUGUGUA CAUUAUACCUUGUA	UUGCC GUU GUGAUCCC
295	GCACAGUG AGAA GCTUG ACCAGAGAAACACACGUGUGUGUA CAUUAUACCUUGUA	CAGCA GAC CACUGUCC
329	AAGCCGAG AGAA GCGU ACCAGAGAAACACACGUGUGUGUA CAUUAUACCUUGUA	AGGCA GUC CUCGGCUU
433	UCCACCCA AGAA GCGC ACCAGAGAAACACACGUGUGUGUA CAUUAUACCUUGUA	GCGCU GCC UGGUGGAA
626	CAUUCUUG AGAA GUGA ACCAGAGAAACACACGUGUGUGUA CAUUAUACCUUGUA	UOACU GUU CAAGAAGU
806	UCCCCAGG AGAA GCAU ACCAGAGAAACACACGUGUGUGUA CAUUAUACCUUGUA	AUGCU GAC CCUGGAGA
849	UCCACUGA AGAA GUGG ACCAGAGAAACACACGUGUGUGUA CAUUAUACCUUGUA	COACU GCC UCAGUGGA
915	AGGGUCUG AGAA GCGA ACCAGAGAAACACACGUGUGUGUA CAUUAUACCUUGUA	UGGCG GAC CAGACCCU
1182	ACTUCCAA AGAA GCAG ACCAGAGAAACACACGUGUGUGUA CAUUAUACCUUGUA	CUGCG GCC UUGGAGGU
1307	AUGUAAGA AGAA GCTUG ACCAGAGAAACACACGUGUGUGUA CAUUAUACCUUGUA	CAGCA GAC UCUUACAU
1357	UCCUUUCC AGAA GCAG ACCAGAGAAACACACGUGUGUGUA CAUUAUACCUUGUA	CUGCA GCC GGAAGGCA
1382	UCCCGAUA AGAA GCGG ACCAGAGAAACACACGUGUGUGUA CAUUAUACCUUGUA	CGGCU GCC UAUUGGGA
1858	GCCCACCA AGAA GUGG ACCAGAGAAACACACGUGUGUGUA CAUUAUACCUUGUA	CUACA GCC UUGUGGGC
1887	AGAAAGGA AGAA GCTU ACCAGAGAAACACACGUGUGUGUA CAUUAUACCUUGUA	AGGCU GAC UUCUUUCU
2012	GAGUUEGG AGAA GUGU ACCAGAGAAACACACGUGUGUGUA CAUUAUACCUUGUA	ACACU GUC CCCAACTC
2303	AGACUCCA AGAA GUGG ACCAGAGAAACACACGUGUGUGUA CAUUAUACCUUGUA	CCACA GCC UGGAGUCU
2539	CTUCCCCAC AGAA GCTU ACCAGAGAAACACACGUGUGUGUA CAUUAUACCUUGUA	AAGCU GUU GUGGAGG

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Table 9: Rat ICAM HH Ribozyme Target Sequence

nt. Position	HH Target sequence	nt. Position	HH Target Sequence
11	GAUCCAAU U CACACUGA	394	GGGGUGCU U CUGAACAG
23	GCUGACUU C CUUCUCUA	420	GCAACCCU C CCAGOGCA
26	GAACUGCU C UUCUCUUU	425	CUUGGCUU U CUGGCCAC
31	CCUCUGCU C CUGGUCUU	427	UCCUGUUU U AAAAACCA
34	CUGAAGCU C AGAUAUAC	450	AAGAACCU C AUCCUGCG
40	CUCAAGGU A CAAGCCCC	451	GGGUACUU C CCCCAGGC
48	GAGAACCU C GGGCUGGG	456	CUUGGCUU C UGCCACCA
54	CCCGGCUU C CCUGAGCC	495	GCCACCAU C ACUGUGUA
58	CCUGGCUU U UAGCUCUU	510	GUGGUGCU C CGUGGGAA
64	CAUUGGCU U CAACCCGU	564	GAAAADGU U CCAACCCAC
96	CCUCUGCU C CUGGUCUU	592	GGGAGUAU C ACCAGGGA
102	CUCCUGGU C CUGGUGGC	607	GAGCCAAU U UCUCAUGC
108	GGACUGCU U GGGGAACU	608	AGCCAAAU U CUCAUGCU
115	UCCUACCU U UGUUCCCA	609	GCCAAUUU C UCAUGCUU
119	GACACUGU C CCCAACUC	611	CAAUUUUU C AUGCUUCA
120	GUUGUGAU C CCGGGGCC	656	GUCAUGU U CAAGAADG
146	CCAGACCU U GGAACUCC	657	UCACUGUU C AAGAADGU
152	ACCGGGCU C CACUCCAA	668	GAACUGCU C UUCUCUUU
158	AUUUCUUU C ACCAGUCA	677	GCAACCCU C CCAGOGCA
165	UGAACAGU A CUUCUUUU	684	AGGCAGCU C CGGACUUU
168	GAAGCCUU C CUGCCUUG	692	CCAGACCU U GGAACUCC
185	GGGUGGUA C CGUGCAGG	693	CGGACUUU C GADCUUCC
209	CAGCCCUU A AUUCUGAC	696	GCCUGUUU C CUGCCUCC
227	GACCAAGU A ACUGUGAA	709	CAGCAUUU A CCCCUCAC
230	CAAGCUGU U GUGGGAGG	720	CUACAACU U UUCAGCUC
237	CUGAAGCU C GACACCCC	723	CAACUUUU C AGCUCCCA
248	GGCCCCCU A CCUUAGGA	735	CUCCUGGU C CUGGUGGC
253	CACUGCCU C AGUGGAGG	738	UCCUGCCU C GGGUGGGA
263	GAGCCAAU U UCUCAUGC	765	ACUGUGCU U UGAGAAAU
267	GAAGCCUU C CUGCCUUG	769	UCUUGUGU U CCCCAGAA
293	GAAGCUCU U CAAGCUGA	770	CUUGUGUU C CCUGGAAG
319	CGGAGGAU C ACAAACGA	785	AGGCCUGU U UCCUGCCU
335	ACUGUGCU U UGAGAACU	786	GGCCUGUU U CCUGCCUC
337	UGUGCUAU A UGGGCCUC	792	CUCCUGGU C CUGGUGGC
338	AAGCUCUU C AAGCUGAG	794	UCCUGCCU C UGAAGCUC
359	CACGCAGU C CUUGGCUU	807	GCUCAGAU A UACCUUGA
367	CAUUGGCU U CAACCCGU	833	CCUGGGGU U GGAGACTUA
374	UUAACCCU C ACCCAACU	846	CUGACAGU U AUUUUUUG
375	AGAAGCCU U CCUGCCUC	851	GCUCACCU U UAGCAGCU
378	ACCAACCU C ACAGGGUA	863	CAUUGGCU U CAACCCGU
386	CGCUGUGU U UUGGAGCU	866	CCAUCCUU C CUUCGACA

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867	GACCACCU	C	CCCACCUA	1421	GGGUACUU	C	CCCCAGGC
869	CUCUUCUU	C	UUGGGAAG	1425	ACCCACCU	C	CUCUGGCU
881	AAUGGCUU	C	AACCCGGG	1429	AUACUUGU	A	GCCUCAGG
885	GACCAAGU	A	ACUGUGAA	1444	AGAAGGCU	C	AGGAGGAG
933	UGUGUAUU	C	GUUCCGAG	1455	GGGAGUAU	C	ACCAGGGA
936	GCAGAGAU	U	UUGGUGCA	1482	AGGGUACU	U	CCCCCAGG
978	UUGAGAAU	C	UACAACUU	1484	ACUGGCUU	U	CCTCUGGC
980	GAGAAUCU	A	CAACUUUU	1493	CCUGGGGU	U	GGAGACTA
986	CUACAACU	U	UUCAGCUC	1500	CGUGAAAU	U	AUGGUCAA
987	UACAACUU	U	UCAGCUCC	1503	GAAAAGUU	U	CCAACCAC
988	ACAACUUU	U	CAGCUCCC	1506	UGGGUACU	A	AUUGUUGG
1005	UUCGUGAU	C	GUGGGGUC	1509	GCCACCAU	C	ACTUGUGA
1006	GUGGGAGU	A	UCACCGAG	1518	GUCCUGGU	C	GCCGUUGU
1023	CCGGAGGU	C	UCAGAAGG	1530	ACCUGGGU	C	AUAUUUGU
1025	GGAGGUCU	C	AGAAGGGG	1533	CUGAUCAU	U	GCGGGGCU
1066	CCUACCUU	U	GUUCCCAA	1551	GUGGCCUU	C	UGCUCGUA
1092	AGAGGGGU	C	UCAGCAGA	1559	UGGGAGUU	C	CCTGUUUA
1093	AGGGGAUU	C	CAGCCCCU	1563	UCCUACCU	U	UGUCCCCA
1125	CCCCRACU	C	UUGUUGAU	1565	UUACACCU	A	UUACCCGC
1163	ACGACGCU	U	CUUUUGCU	1567	ACACCUAU	U	ACCGCCAG
1164	CGACGCUU	C	UUUUGCUC	1584	AGGAAGAU	C	AGGAUUAU
1166	ACGCUUCU	U	UUGCUCUG	1592	CAGGADAU	A	CAAGUUAC
1172	CUUUUGCU	C	UGGGGCUU	1599	UACAAGUU	A	CAGAAGGC
1200	AUCCAAUU	C	ACACUGAA	1651	CCCGGCUU	C	CCUGAGCC
1201	UUGGGCUU	C	UCCACAGG	1661	CUGCACUU	U	GCCUUGGU
1203	GGGCUUCU	C	CACAGGUC	1663	GAACAGAU	C	AAUGGACA
1227	UUGGAACU	C	CAUGUGCU	1678	GAGAACCU	C	GGCCUGGG
1228	GCGGGCUU	C	GUGAUCGU	1680	GGGUUCUU	C	CACAGGUC
1233	CUCUGGCU	C	CUGGUGGC	1681	GGCUGUUG	U	CCTUGCUC
1238	UGUGCUAU	A	UGGUCCUC	1684	CUGCCUGU	A	GACCCUC
1264	GGAAAGAU	C	AUAAGGGU	1690	CCCCACCU	A	CAUACAUU
1267	GUCACUGU	U	CAAGAAUG	1691	CCGGACCU	U	CGAUCUUC
1294	CAGAGAUU	U	UGUGUCAG	1696	CUCCUGGU	C	CUGGUCGC
1295	AGAGGGGU	C	UCAGCAGA	1698	UCAGAUUU	A	CCUGGAGA
1306	AGCAGACU	C	UUACADGC	1737	GAUACAUU	U	CACGGUGC
1321	AACAGAGU	C	UGGGGAAA	1750	GUCCAUUU	A	CACCUAUU
1334	GUUUUGGU	U	CCCAGAGC	1756	CCTCUGCU	C	CUGGUCCU
1344	UCGGUGCU	C	AGGUADCC	1787	GAGAAACU	C	GGCCUGGG
1351	UCAGGCUU	A	AGAGGACU	1790	GACACUGU	C	CCCAACUC
1353	UAGCAGCU	C	AACAADGG	1793	AUGGUCCU	C	ACCCGGAC
1366	AGGGUACU	U	CCCCCAGG	1797	UCCCGUGU	U	AAAAACCA
1367	GGGUACUU	C	CCCCAGGC	1802	GCUACAGU	A	UACCUUGA
1368	GAUGGUGU	C	CCGUCGCC	1812	AACAGAGU	C	UGGGGAAA
1380	CUGCCUAU	C	GGGAUGGU	1813	GCGGGCUU	C	GUGAUGGU
1388	UGGAGACU	A	ACUGGAUG	1825	GCCACCAU	C	ACUGUGUA
1398	CUGGCUUG	C	ACAGGACA	1837	ACCCACCU	C	ACAGGGUA
1402	CUGUGCUU	U	GAGAACTG	1845	AGAGGACU	C	GGAGGGGC
1408	UUGUGAUU	C	GUGGCGUC	1856	CCCCUAUU	C	UGACCCUC
1410	CGAACUAU	C	CAGUGGAC	1861	CAUGUGCU	A	UAUGGUCC

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1865	UAUCCGGU	A	GACACAAG	2198	GAUUGUUU	C	CGAGGUCA
1868	UCACGAGU	C	AUAUAAAU	2199	AGACUCCU	A	CAUGCCAG
1877	ACAGUACU	U	CCCCCAGG	2200	GGGUACUU	C	CCCCAGGC
1901	CUAAAACU	C	AAGGUACA	2201	GGGCUUCU	C	CACAGGUC
1912	GAACAGAU	C	AAUGGACA	2205	UUUUGUGU	C	AGCCACUG
1922	AUGUAAGU	U	AUUGCCUA	2210	UGGAGACU	A	ACUGGAUG
1923	UGGACGCU	C	ACCUUUAU	2220	GAGAAACU	C	GGCCUGGG
1928	GUCCAGAU	A	UACCUGEA	2224	ACAUACAU	U	CCUACCCU
1930	UGGAGACU	A	ACCGGAGG	2226	CUGGACCU	C	AGGCCACA
1964	AGAGAUUU	U	GUUGCAGC	2233	UCAUGCUU	C	ACAGAACU
1983	GAGAAACU	C	GGCCUGGG	2242	ACACAGCU	C	UCAGUAGU
1996	UGGAAGCU	C	UUCAAGCU	2248	CUCCUGGU	C	CUUGUCCG
2005	ADGUAAGU	U	AUUGCCUA	2254	ADCCAAUU	C	ACACUGAA
2013	CGCUGCCU	A	UCGGGAGU	2259	GAUCCAUU	U	CAUGGUGC
2015	CUGCCUAU	C	GGGAGGGU	2260	AUCACAUU	C	ACGGUGCU
2020	UAUUGAGU	A	CCCUGUAC	2266	AUCAGGAU	A	UACAAGUU
2039	CGGAGGAU	C	ACAAACGA	2274	GAGCAGGU	U	AACAUGUA
2040	CCUGACCU	C	CUGGAGGU	2279	GGAAAGAU	C	AUACGGGU
2057	CGGUCCCU	C	CAADGGCU	2282	ACAGUUAU	U	UAUUGAGU
2061	GCGUCCAU	U	UACAACUA	2288	GOCCUGGU	C	CUCCAADG
2071	AUAUUGU	A	GCCUCAGG	2291	CAGGAUAU	A	CAAGUUAC
2076	UGUAGCCU	C	AGGCCUAA	2321	GGAAAGAU	C	AUAOGGGU
2097	CCAACUCU	U	GUUGAUGU	2338	UUUGGGCU	C	UCCACAGG
2098	CCUGACCU	C	CUGGAGGU	2339	GGGUACUU	C	CCCCAGGC
2115	UUCCGACU	A	GGGUCCUG	2341	GGGCCUGU	C	GGUGCUCA
2128	AGUGCGGU	A	CCAUGAUC	2344	CUGCCUGU	A	GAUCCUCU
2130	GCCUGUUU	C	CUGCCUCU	2358	CCUGGCCU	C	CUCCACCA
2145	CCAACUCU	U	GUUGAUGU	2359	CCAUCCAU	C	CCACAGAA
2152	UUGAGAAU	C	UACAACUU	2360	CUUGUGUU	C	CCUGGAAG
2156	UGACAGGU	A	UUUAUUGA	2376	GAACUGCU	C	UUCCUCUU
2158	UGAUGUAU	U	UAUUAUUU	2377	GACUUCCU	U	CUUAUUUA
2159	GAUGUAUU	U	AUUAAUUC	2378	GCTGAUUU	C	UUUACCGA
2160	ADGUUAUU	A	UUAAUCCA	2379	CUGCCUUU	C	CUUUUGUG
2162	ACAUUCCU	A	CCUUUGUU	2380	UGAUUCCU	U	UCAOGAGU
2163	UAUUUAUU	A	AUUCAGAG	2382	AUUUCUUU	C	ACGAGUCA
2166	UGAUGUAU	U	UAUUAAUU	2384	UAUCCGGU	A	GACACAAG
2167	GAUGUAUU	U	AUUAAUUC	2399	UAAAUACU	A	UGUGGAGC
2170	GUUUUAUU	U	AAUUCAGA	2401	UGUGCUAU	A	UGGUCCUC
2171	CAGUUAUU	U	AUUGAGUA	2411	CAAUUUUU	C	AUGCUUCA
2173	UGUGCUAU	A	UGGUCCUC	2417	AUCAGGAU	A	UACAAGUU
2174	UCUCUAUU	A	CCCCUGCU	2418	UCAUGCUU	C	ACAGAACU
2175	AUUUCUUU	C	ACGAGUCA	2425	UUAUUAUU	U	CAGAGUUC
2176	GAAAAGUU	U	CCAACCCAC	2426	CCUGGGGU	U	GGAGACUA
2183	UGACAGUU	A	UUUAUUGA	2433	UCAGAGUU	C	UGACAGUU
2185	ACAGUUAU	U	UAUUGAGU	2434	CGGAGGAU	C	ACAAACGA
2186	CAGUUUAU	U	AUUGAGUA	2448	UGAACAGU	A	CUUCCCCC
2187	AGUUUAUU	A	UUAGAGUAC	2449	GAAGCCUU	C	CUGCCUCC
2189	UUUUUAUU	U	GAGUACCC	2451	GGCCUGUU	U	CCUGCCUC
2196	CUGACAGU	U	AUUUAUUG	2452	GCCUGUUU	C	CUGCCUCU

2455	ACAUCUU A CCUUGUU	2761	CGACUUU C GADUUCC
2459	CCUGGCU C CUCCACA	2765	CUUUGCU C UGGGGCU
2460	CUUACCU U GUUCCAA	2769	UUCUUU U ACCCCUG
2479	UUAACCU A UUAAGGC	2797	CGUGAAU U AUGGUCAA
2480	GUUGGCU U GUGAGCC	2803	CUAGGCU U CACAGAAC
2483	ACCUUGU U CCCAAGU	2804	UCAGGCU C ACAGAAU
2484	CCUUGUU C CCAAGGC	2813	GUUCCAU C CUGACCU
2492	GACCACU C CCAACUA	2815	CGACUUU C GADUUCC
2504	ACCUACU A CAUUCUA	2821	CCUGACCU C CUGGAGU
2508	ACAACAU U CCUACCU	2822	UACAACU U UCAGUCC
2509	CAUACAU C CUACCUU	2823	CAACUUU C AGCUCCA
2510	GUUACUU A CACCUAU	2829	UUGGGCU C AGGUUCC
2520	ACCUUGU U CCCAAGU	2837	CACAGGU A CUUCCCC
2521	CCUUGUU C CCAAGGC	2840	GCACCCU C CCAGGCA
2533	ACAGCAU U ACCCCCA	2847	UUACCCU C ACCACCU
2540	UUGGGCU C AGGUUCC	2853	UUGGACU U CCGACUAG
2545	AGGCAGU C CGACUUU	2860	UCUUGUU U CCUGGAA
2568	CAGACAU U UGUGCAG	2872	GGGCGU C GGUGCUA
2579	CCUGACU U UGCCCGG	2877	UGGAGCU C CCAGCAC
2585	UGGCGU A GACCUUC	2899	AGGCAGU C CGACUUU
2588	UGGCGU C CCACAGC	2900	GGUGACU U CCUUCUU
2591	CUUUCUU C UUGGAG	2904	GAACGCU C UUCUCCU
2593	UCUUAU A CCCCUGU	2905	GGUGACU U CCUUCUU
2596	CUUUGGU C CUGGCGC	2906	GUUGAUU A UUAUUAA
2601	UGUGCUU A UGUUCCU	2907	CUUUCUU C CUUUGCG
2602	GUUUGGU C GCGUGU	2908	UGAGUUA U UAUUAUU
2607	GUUGGAGU A UCAACAG	2909	GAACGCU C UUCUCCU
2608	CUUAGCU C CCGGGGA	2910	ACUUCUU C UCUAUAC
2609	UGGAGCU A ACUGGAG	2911	UUCUUCU C UAUUACC
2620	UCAGAGU C UGACAGU	2912	AUGUAUU A UUAUUCA
2626	CUUCAGU A GCGUGCU	2913	UGUGAUU C GUUCCAG
2628	UACAACU U UCAGUCC	2914	GUUUUAU U AAUUCAG
2635	UCAAGAU C CAUUCAC	2915	UAUUUAU A AUUCAGG
2640	GUUCAGU A UCCAUCA	2916	CUUUCUU C UUGGAGG
2641	CCCCACU A CAUACAU	2917	CUUUCUU U GGAAGAC
2642	GUUUGUU C CUGGCGU	2918	AUUUCUU C ACGAGUA
2653	CCACAGU C AGGGGCU	2919	UUUUGGU C AGCCACG
2659	AGAAGGU C CUGAAGC	2931	GAUGGUGU C CGGUGGC
2689	ACUAGGU C CUGAAGC	2933	UGGAGCU C CCAGCAC
2691	UCAGGCU A AGAGGAC	2941	CAGUACU C CCCCAGC
2700	AGGUAU U CCCCAGG	2951	ACCAAGU U CCUCUAC
2704	GACCACU C CCAACUA	2952	CCGACU U CGACUUC
2711	CCUACCU U AGGAGGU	2955	UGCUUCU C UGACUUG
2712	CUUACCU A GGAAGGU	2956	CUUUCUU U GAUUAUU
2721	GAAGAUA C AUAGGCU	2961	UUUUGGU C AGCCACU
2724	AAGAUUA A CCGGUUG	2962	UGUGUAU C GUUCCAG
2744	GGUGGAGU C CUGCAGG	2965	CUUUGAU C AAUAAAG
2750	GUUUGU U UAAAAAC	2966	UGGAAGU C UUCAAGU
2759	GACGAU A UCGAGU	2969	GAACAAU A AAGUUUA

2975	UGGAAGCU C UUCAAGCU
2976	UADAUGGU C CUCACCUG
2977	GAAGCUCU U CAAGCUGA

Table 10: Rat ICAM HH Ribozyme Sequences

nt. Position	Rat HH Ribozyme Sequence
11	UCAGUGUG CUGADGAGGCCGAAAGGCCGAA AUUGGAGC
23	UAGAGAAG CUGADGAGGCCGAAAGGCCGAA AAGUCAGC
26	AAGAGGAA CUGADGAGGCCGAAAGGCCGAA AGCAGUUC
31	AGGACCAG CUGADGAGGCCGAAAGGCCGAA AGCAGAGG
34	GUUAUUCU CUGADGAGGCCGAAAGGCCGAA AGCUUCAG
40	GGGGCUUG CUGADGAGGCCGAAAGGCCGAA ACCUUGAG
48	CCAGGCC CUGADGAGGCCGAAAGGCCGAA AGGUUCUC
54	GGUCAGG CUGADGAGGCCGAAAGGCCGAA AGGCGGGG
58	GGGAGCUA CUGADGAGGCCGAAAGGCCGAA AGGCAAGG
64	AGGGUUG CUGADGAGGCCGAAAGGCCGAA AGCCAUUG
96	AGGACCAG CUGADGAGGCCGAAAGGCCGAA AGCAGAGG
102	GCGACCAG CUGADGAGGCCGAAAGGCCGAA ACCAGGAG
108	AGUCCCC CUGADGAGGCCGAAAGGCCGAA AGCAGUCC
115	UGGGAACA CUGADGAGGCCGAAAGGCCGAA AGGUAGGA
119	GAGUUGGG CUGADGAGGCCGAAAGGCCGAA ACAGUGUC
120	GGCCCGGG CUGADGAGGCCGAAAGGCCGAA AUCACAAC
146	GGAGUUC CUGADGAGGCCGAAAGGCCGAA AGGUUCGG
152	UUGAGGUG CUGADGAGGCCGAAAGGCCGAA AGCCGGGU
158	UGACUUGU CUGADGAGGCCGAAAGGCCGAA AAAGAAAU
165	GGGGGAAG CUGADGAGGCCGAAAGGCCGAA ACUGUACA
168	CGAGGCAG CUGADGAGGCCGAAAGGCCGAA AAGGCUUC
185	CCUGCACG CUGADGAGGCCGAAAGGCCGAA AUCCACCC
209	GGUCAGAU CUGADGAGGCCGAAAGGCCGAA AGGGGCTG
227	UUCACAGU CUGADGAGGCCGAAAGGCCGAA ACUUGGUC
230	CCUCCAC CUGADGAGGCCGAAAGGCCGAA ACAGCUUG
237	GGGGUGUC CUGADGAGGCCGAAAGGCCGAA AGCUUCAG
248	UCCUAAGG CUGADGAGGCCGAAAGGCCGAA AGGGGGCC
253	CCUCCACT CUGADGAGGCCGAAAGGCCGAA AGGCAGUG
263	GCAUGAGA CUGADGAGGCCGAAAGGCCGAA AUUGGCTC
267	CGAGGCAG CUGADGAGGCCGAAAGGCCGAA AAGGCUUC
293	UCAGCUUG CUGADGAGGCCGAAAGGCCGAA AGAGCUUC
319	UCGUUGU CUGADGAGGCCGAAAGGCCGAA AUCCUCCG
335	AGUUCUCA CUGADGAGGCCGAAAGGCCGAA AGCACAGU
337	GAGGACCA CUGADGAGGCCGAAAGGCCGAA AUAGCACA
338	CUCAGCUU CUGADGAGGCCGAAAGGCCGAA AAGAGCUU
359	AAGCCGAG CUGADGAGGCCGAAAGGCCGAA ACUGGGUG
367	ACGGGUUG CUGADGAGGCCGAAAGGCCGAA AGCCAUUG
374	AGGUGGGU CUGADGAGGCCGAAAGGCCGAA AGGGGUAA
375	GAGGCAGG CUGADGAGGCCGAAAGGCCGAA AGGCUUCU
378	UACCCUGU CUGADGAGGCCGAAAGGCCGAA AGGUGGGU
386	AGCUCCAA CUGADGAGGCCGAAAGGCCGAA ACACAGCG

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394	CUGUUCAG	CUGADGAGGCOGAAAGGCCOGAA	AGCACCCAC
420	UGGCGUGG	CUGADGAGGCOGAAAGGCCOGAA	AGGGGUGC
425	GGGGCAG	CUGADGAGGCOGAAAGGCCOGAA	AGCCGAGG
427	UGGUUUUU	CUGADGAGGCOGAAAGGCCOGAA	AACAGGGA
450	CGCAGGAU	CUGADGAGGCOGAAAGGCCOGAA	AGGUUCUU
451	GCCCGGGG	CUGADGAGGCOGAAAGGCCOGAA	AAGUACCC
456	UGGUGGCA	CUGADGAGGCOGAAAGGCCOGAA	AAGCCGAG
495	UACACAGU	CUGADGAGGCOGAAAGGCCOGAA	ADGGUGGC
510	UUCOCACG	CUGADGAGGCOGAAAGGCCOGAA	AGCAGCAC
564	GGGGUUGG	CUGADGAGGCOGAAAGGCCOGAA	ACAUUUUC
592	UCCCUUGU	CUGADGAGGCOGAAAGGCCOGAA	AUACUCCC
607	GCAUGAGA	CUGADGAGGCOGAAAGGCCOGAA	ADUGGCUU
608	AGCAUGAG	CUGADGAGGCOGAAAGGCCOGAA	AAUUGGCU
609	AAGCAUGA	CUGADGAGGCOGAAAGGCCOGAA	AAAUUGGC
611	UGAAGCAU	CUGADGAGGCOGAAAGGCCOGAA	AGAAADUG
656	CAUUCUUG	CUGADGAGGCOGAAAGGCCOGAA	ACAGUGAC
657	ACAUUCUU	CUGADGAGGCOGAAAGGCCOGAA	AACAGUGA
668	AAGAGGAA	CUGADGAGGCOGAAAGGCCOGAA	AGCAUUCU
677	UGGCGUGG	CUGADGAGGCOGAAAGGCCOGAA	AGGGGUGC
684	AAAGUCCG	CUGADGAGGCOGAAAGGCCOGAA	AGCUGCCU
692	GGAGUCC	CUGADGAGGCOGAAAGGCCOGAA	AGGUUUGG
693	GGAGAUUC	CUGADGAGGCOGAAAGGCCOGAA	AAAGUCCG
696	AGAGGCAG	CUGADGAGGCOGAAAGGCCOGAA	AAACAGGC
709	GUGAGGGG	CUGADGAGGCOGAAAGGCCOGAA	AAAUUGCU
720	GAGCUGAA	CUGADGAGGCOGAAAGGCCOGAA	AGUUGUAG
723	UGGGAGCU	CUGADGAGGCOGAAAGGCCOGAA	AAAAGUUG
735	GCGACCAAG	CUGADGAGGCOGAAAGGCCOGAA	ACCAGGAG
738	UCCACCCU	CUGADGAGGCOGAAAGGCCOGAA	AGGCAGGA
765	AGUUCUCA	CUGADGAGGCOGAAAGGCCOGAA	AGCACAGU
769	UUCACAGG	CUGADGAGGCOGAAAGGCCOGAA	ACACAAGA
770	CUUCCAGG	CUGADGAGGCOGAAAGGCCOGAA	AACACAAG
785	AGGCAGGA	CUGADGAGGCOGAAAGGCCOGAA	ACAGGCCU
786	GAGGCAGG	CUGADGAGGCOGAAAGGCCOGAA	AACAGGCC
792	GCGACCAAG	CUGADGAGGCOGAAAGGCCOGAA	ACCAGGAG
794	GAGCUUCA	CUGADGAGGCOGAAAGGCCOGAA	AGGCAGGA
807	UCCAGGUA	CUGADGAGGCOGAAAGGCCOGAA	AUCUGAGC
833	UAGUCUCC	CUGADGAGGCOGAAAGGCCOGAA	ACCCAGG
846	CAUUAUU	CUGADGAGGCOGAAAGGCCOGAA	ACUGUCAG
851	AGCUGCUA	CUGADGAGGCOGAAAGGCCOGAA	AGGUGAGC
863	AOGGGUUG	CUGADGAGGCOGAAAGGCCOGAA	AGCCAUUG
866	UGUCAGAG	CUGADGAGGCOGAAAGGCCOGAA	AAGCAUGG
867	UAGGUGGG	CUGADGAGGCOGAAAGGCCOGAA	AGGUGGUC
869	CUUCGCAA	CUGADGAGGCOGAAAGGCCOGAA	AGGAAGAG
881	CACGGGUU	CUGADGAGGCOGAAAGGCCOGAA	AAGCCAUU
885	UUCACAGU	CUGADGAGGCOGAAAGGCCOGAA	ACUUGGUC
933	CUGGGAAC	CUGADGAGGCOGAAAGGCCOGAA	AAUACACA
936	UGACACAA	CUGADGAGGCOGAAAGGCCOGAA	AUCUCUGC
978	AAGUUGUA	CUGADGAGGCOGAAAGGCCOGAA	AUUCUCAA
980	AAAAGUUG	CUGADGAGGCOGAAAGGCCOGAA	AGAUCUC

986	GAGCUGAA	CUGAUGAGGCCGAAAGGCCGAA	AGUUGUAG
987	GGAGCUGA	CUGAUGAGGCCGAAAGGCCGAA	AAGUUGUA
988	GGGAGCUG	CUGAUGAGGCCGAAAGGCCGAA	AAAGUUGU
1005	GACGCCAC	CUGAUGAGGCCGAAAGGCCGAA	AUCACGAA
1006	CCUGGUGA	CUGAUGAGGCCGAAAGGCCGAA	ACUCCAC
1023	CCUUCUGA	CUGAUGAGGCCGAAAGGCCGAA	ACCUCCG
1025	CCCCUUCU	CUGAUGAGGCCGAAAGGCCGAA	AGACCUCC
1066	UUGGGAAC	CUGAUGAGGCCGAAAGGCCGAA	AAGGUAGG
1092	UCUGCUGA	CUGAUGAGGCCGAAAGGCCGAA	AACCCUCU
1093	AGGGGCUG	CUGAUGAGGCCGAAAGGCCGAA	AGUCCCU
1125	AUCAACAA	CUGAUGAGGCCGAAAGGCCGAA	AGUUGGG
1163	AGCAAAAG	CUGAUGAGGCCGAAAGGCCGAA	AGGUGUGU
1164	GAGCAAAA	CUGAUGAGGCCGAAAGGCCGAA	AAGCGUG
1166	CAGAGCAA	CUGAUGAGGCCGAAAGGCCGAA	AGAAGCGU
1172	AGGCCGCA	CUGAUGAGGCCGAAAGGCCGAA	AGCAAAAG
1200	UUCAGUGU	CUGAUGAGGCCGAAAGGCCGAA	AATUGGAT
1201	CCUGUGGA	CUGAUGAGGCCGAAAGGCCGAA	AAGCCCAA
1203	GACCUUGG	CUGAUGAGGCCGAAAGGCCGAA	AGAAGCC
1227	AGCACADG	CUGAUGAGGCCGAAAGGCCGAA	AGUUCCAA
1228	AOGAUCAC	CUGAUGAGGCCGAAAGGCCGAA	AAGCCCG
1233	GCGACCA	CUGAUGAGGCCGAAAGGCCGAA	ACAGGAG
1238	GAGGACCA	CUGAUGAGGCCGAAAGGCCGAA	ATAGCACA
1264	ACCCGUAT	CUGAUGAGGCCGAAAGGCCGAA	AUCUUCC
1267	CAUUCUUG	CUGAUGAGGCCGAAAGGCCGAA	ACAGUGAC
1294	CUGACACA	CUGAUGAGGCCGAAAGGCCGAA	AATUCUG
1295	UCUGCUGA	CUGAUGAGGCCGAAAGGCCGAA	AACCCUCU
1306	GCAUGUAA	CUGAUGAGGCCGAAAGGCCGAA	AGUCUGCU
1321	UUUCCCA	CUGAUGAGGCCGAAAGGCCGAA	ACTUCUGU
1334	GCUCUGGG	CUGAUGAGGCCGAAAGGCCGAA	ACGAATAC
1344	GEATACCU	CUGAUGAGGCCGAAAGGCCGAA	AGCACCGA
1351	AGUCCUCU	CUGAUGAGGCCGAAAGGCCGAA	AGGCCUGA
1353	CCAUUGUU	CUGAUGAGGCCGAAAGGCCGAA	AGCUGCUA
1366	CCUGGGGG	CUGAUGAGGCCGAAAGGCCGAA	AGUACCCU
1367	GCCUGGGG	CUGAUGAGGCCGAAAGGCCGAA	AAGUACCC
1368	GGCAGCGG	CUGAUGAGGCCGAAAGGCCGAA	ACACCAAC
1380	ACCAUCCC	CUGAUGAGGCCGAAAGGCCGAA	ATAGGCAG
1388	CADCCAGU	CUGAUGAGGCCGAAAGGCCGAA	AGUCUCCA
1398	UGUCCUGU	CUGAUGAGGCCGAAAGGCCGAA	ACAGCCAG
1402	CAGUUCUC	CUGAUGAGGCCGAAAGGCCGAA	AAGCACAG
1408	GACGCCAC	CUGAUGAGGCCGAAAGGCCGAA	AUCAAGAA
1410	GUCCACUC	CUGAUGAGGCCGAAAGGCCGAA	ATAGUUCG
1421	GCCUGGGG	CUGAUGAGGCCGAAAGGCCGAA	AAGUACCC
1425	AGCCAGAG	CUGAUGAGGCCGAAAGGCCGAA	AGGUGGGU
1429	CCUGAGGC	CUGAUGAGGCCGAAAGGCCGAA	ACAAGUAT
1444	CUCUCCU	CUGAUGAGGCCGAAAGGCCGAA	AGCCUUCU
1455	UCCUGGU	CUGAUGAGGCCGAAAGGCCGAA	ATACUCCC
1482	CCUGGGGG	CUGAUGAGGCCGAAAGGCCGAA	AGUACCCU
1484	GCAAGAGG	CUGAUGAGGCCGAAAGGCCGAA	AGAGCAGU
1493	UAGUCUCC	CUGAUGAGGCCGAAAGGCCGAA	AACCCAGG

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1500	UUGA	CCAU	CUGAUGAGGCCGAAAGGCCGAA	AUUU	CACG
1503	GUGGU	UGG	CUGAUGAGGCCGAAAGGCCGAA	ACAU	UUUC
1506	CCAACA	UAU	CUGAUGAGGCCGAAAGGCCGAA	AUGA	CCCA
1509	UACACAGU		CUGAUGAGGCCGAAAGGCCGAA	AUGG	UGGC
1518	ACAACGGC		CUGAUGAGGCCGAAAGGCCGAA	ACCAG	GAC
1530	ACAUAUAU		CUGAUGAGGCCGAAAGGCCGAA	ACCCAG	GU
1533	AAGCCCGC		CUGAUGAGGCCGAAAGGCCGAA	AUGAU	CAG
1551	UACGAGCA		CUGAUGAGGCCGAAAGGCCGAA	AGG	CCAC
1559	UAAACAGG		CUGAUGAGGCCGAAAGGCCGAA	ACU	CCCA
1563	UGGGAACA		CUGAUGAGGCCGAAAGGCCGAA	AGGU	AGEA
1565	GGCGGUA		CUGAUGAGGCCGAAAGGCCGAA	AGGU	GUA
1567	CUGCGGU		CUGAUGAGGCCGAAAGGCCGAA	AUAG	GUU
1584	UAUAUCCU		CUGAUGAGGCCGAAAGGCCGAA	AUCU	UCCU
1592	GUAACUUG		CUGAUGAGGCCGAAAGGCCGAA	AUAU	CCUG
1599	GCCUUCUG		CUGAUGAGGCCGAAAGGCCGAA	AACU	UGUA
1651	GGCUCAGG		CUGAUGAGGCCGAAAGGCCGAA	AGG	CGGG
1661	ACCAGGGC		CUGAUGAGGCCGAAAGGCCGAA	AAGU	CAG
1663	UUC	CCAU	CUGAUGAGGCCGAAAGGCCGAA	AUCU	GUUC
1678	CCCAGGCC		CUGAUGAGGCCGAAAGGCCGAA	AGGU	UCC
1680	GACCUUG		CUGAUGAGGCCGAAAGGCCGAA	AGA	AGCC
1681	GAGGCAGG		CUGAUGAGGCCGAAAGGCCGAA	AAC	AGCC
1684	GAGAGGUC		CUGAUGAGGCCGAAAGGCCGAA	ACG	AGCAG
1690	AADGUADG		CUGAUGAGGCCGAAAGGCCGAA	AGGU	GGG
1691	GAAGAUCC		CUGAUGAGGCCGAAAGGCCGAA	AAGU	CCGG
1696	GCGACCA		CUGAUGAGGCCGAAAGGCCGAA	ACC	AGGAG
1698	UCUCCAGG		CUGAUGAGGCCGAAAGGCCGAA	AUAU	CCGA
1737	GCACCGUG		CUGAUGAGGCCGAAAGGCCGAA	AUGU	GAUC
1750	AAUAGGGG		CUGAUGAGGCCGAAAGGCCGAA	AAAU	GGAC
1756	AGGACCAG		CUGAUGAGGCCGAAAGGCCGAA	AGC	AGAGG
1787	CCCAGGCC		CUGAUGAGGCCGAAAGGCCGAA	AGGU	UCC
1790	GAGUUGGG		CUGAUGAGGCCGAAAGGCCGAA	ACAG	UGUC
1793	GUCCAGGU		CUGAUGAGGCCGAAAGGCCGAA	AGGA	CCAU
1797	UGGUUUUU		CUGAUGAGGCCGAAAGGCCGAA	AAC	AGGA
1802	UCCAGGUA		CUGAUGAGGCCGAAAGGCCGAA	AUCU	GAGC
1812	UUUCCCA		CUGAUGAGGCCGAAAGGCCGAA	ACCU	UGUU
1813	ACGAUCCAC		CUGAUGAGGCCGAAAGGCCGAA	AAGC	CCGC
1825	UACACAGU		CUGAUGAGGCCGAAAGGCCGAA	AUGG	UGGC
1837	UAUCCUGU		CUGAUGAGGCCGAAAGGCCGAA	AGGU	GGGU
1845	GUUCCUCC		CUGAUGAGGCCGAAAGGCCGAA	AGU	CCUCU
1856	GCAGGUCA		CUGAUGAGGCCGAAAGGCCGAA	AUA	AGGG
1861	GGACCAUA		CUGAUGAGGCCGAAAGGCCGAA	AGCA	CAUG
1865	CUUGUGUC		CUGAUGAGGCCGAAAGGCCGAA	ACCG	GAUA
1868	AUUUAUAU		CUGAUGAGGCCGAAAGGCCGAA	ACUC	GUGA
1877	CCUGGGGG		CUGAUGAGGCCGAAAGGCCGAA	AGUA	CUGU
1901	UGUACCUU		CUGAUGAGGCCGAAAGGCCGAA	AGUU	UUAG
1912	UGUCCAUU		CUGAUGAGGCCGAAAGGCCGAA	AUCU	GUUC
1922	UAGGCAAU		CUGAUGAGGCCGAAAGGCCGAA	ACUA	CAU
1923	CUAAAGGU		CUGAUGAGGCCGAAAGGCCGAA	AGCG	UCCA
1928	UCCAGGUA		CUGAUGAGGCCGAAAGGCCGAA	AUCU	GAGC

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1930	CAUCCAGU	CUGAUGAGGCGAAAGGCGGAA	AGUCUCCA
1964	GCUGACAC	CUGAUGAGGCGAAAGGCGGAA	AAAUCCUC
1983	CCCAGGCC	CUGAUGAGGCGAAAGGCGGAA	AGGUUCUC
1996	AGCUUGAA	CUGAUGAGGCGAAAGGCGGAA	AGCUUCCA
2005	UAGGCAAU	CUGAUGAGGCGAAAGGCGGAA	ACUUAACU
2013	CAUCCCGA	CUGAUGAGGCGAAAGGCGGAA	AGGCAGCG
2015	ACCAUCCC	CUGAUGAGGCGAAAGGCGGAA	AUAAGCAG
2020	GUACAGGG	CUGAUGAGGCGAAAGGCGGAA	ACUCAIDA
2039	UCGUUUGU	CUGAUGAGGCGAAAGGCGGAA	AUCCUCCG
2040	ACCUCCAG	CUGAUGAGGCGAAAGGCGGAA	AGGUCAGG
2057	AGCCAUUG	CUGAUGAGGCGAAAGGCGGAA	AGGACCAG
2061	UAGGUGUA	CUGAUGAGGCGAAAGGCGGAA	AUGGACGC
2071	CCUGAGGC	CUGAUGAGGCGAAAGGCGGAA	ACAAGUAU
2076	UUAGGCTU	CUGAUGAGGCGAAAGGCGGAA	AGGCUACA
2097	ACAUCAAC	CUGAUGAGGCGAAAGGCGGAA	AGAGUUGG
2098	ACCUCCAG	CUGAUGAGGCGAAAGGCGGAA	AGGUCAGG
2115	CAGGACCC	CUGAUGAGGCGAAAGGCGGAA	AGUCCGAA
2128	GAUCAUGG	CUGAUGAGGCGAAAGGCGGAA	ACAGCACT
2130	AGAGGCAG	CUGAUGAGGCGAAAGGCGGAA	AAACAGGC
2145	ACAUCAAC	CUGAUGAGGCGAAAGGCGGAA	AGAGUUGG
2152	AAGUUGUA	CUGAUGAGGCGAAAGGCGGAA	AUUCUCAA
2156	UCAAUAAA	CUGAUGAGGCGAAAGGCGGAA	AACUGUCA
2158	AAUUAADA	CUGAUGAGGCGAAAGGCGGAA	AUAACUCA
2159	GAUUAUAU	CUGAUGAGGCGAAAGGCGGAA	AAUACAUU
2160	UGAAUUAU	CUGAUGAGGCGAAAGGCGGAA	AAAUACAU
2162	AACAAAGG	CUGAUGAGGCGAAAGGCGGAA	AGGAADGU
2163	CUCUGAAU	CUGAUGAGGCGAAAGGCGGAA	AAUAUAUA
2166	AAUUAADA	CUGAUGAGGCGAAAGGCGGAA	AUAACUCA
2167	GAUUAUAU	CUGAUGAGGCGAAAGGCGGAA	AAUACAUU
2170	UCUGAAAU	CUGAUGAGGCGAAAGGCGGAA	AUAUAUAC
2171	UACUCAAU	CUGAUGAGGCGAAAGGCGGAA	AAUAACUG
2173	GAGGACCA	CUGAUGAGGCGAAAGGCGGAA	AUAAGCAU
2174	AGCAGGGG	CUGAUGAGGCGAAAGGCGGAA	AAUAAGAG
2175	UGACUUGU	CUGAUGAGGCGAAAGGCGGAA	AAAGAAAU
2176	GUGGUUGG	CUGAUGAGGCGAAAGGCGGAA	ACAUUUUC
2183	UCAAUAAA	CUGAUGAGGCGAAAGGCGGAA	AACUGUCA
2185	ACUCAADA	CUGAUGAGGCGAAAGGCGGAA	AUAACUGU
2186	UACUCAAU	CUGAUGAGGCGAAAGGCGGAA	AAUAACUG
2187	GUACUCAA	CUGAUGAGGCGAAAGGCGGAA	AAAUAACT
2189	GGGUACUC	CUGAUGAGGCGAAAGGCGGAA	AUAUAUAU
2196	CAAUUAAU	CUGAUGAGGCGAAAGGCGGAA	ACUGUCAG
2198	UGACCUUG	CUGAUGAGGCGAAAGGCGGAA	AGACAUCU
2199	CUGGCAUG	CUGAUGAGGCGAAAGGCGGAA	AAGAGUCU
2200	GCCUGGGG	CUGAUGAGGCGAAAGGCGGAA	AAGUACCC
2201	GACCUUGU	CUGAUGAGGCGAAAGGCGGAA	AGAAGCCC
2205	CAGUGGCU	CUGAUGAGGCGAAAGGCGGAA	ACACAAAA
2210	CAUCCAGU	CUGAUGAGGCGAAAGGCGGAA	AGUCUCCA
2220	CCCAGGCC	CUGAUGAGGCGAAAGGCGGAA	AGGUUCUC
2224	AAGGUAGG	CUGAUGAGGCGAAAGGCGGAA	AUGUAUGU

2226	UGUGGCTU	CUGAUGAGGCGAAAGGCGGAA	AGGUCCAG
2233	AGUUCUGU	CUGAUGAGGCGAAAGGCGGAA	AAGCAUGA
2242	ACUACUGA	CUGAUGAGGCGAAAGGCGGAA	AGCUGUGU
2248	GCGAOCAG	CUGAUGAGGCGAAAGGCGGAA	ACCAGSAG
2254	UUCAGUGU	CUGAUGAGGCGAAAGGCGGAA	AAUUGGAU
2259	GCACCGUG	CUGAUGAGGCGAAAGGCGGAA	ADGUGAUC
2260	AGCACCGU	CUGAUGAGGCGAAAGGCGGAA	AAUGUGAU
2266	AACUUGUA	CUGAUGAGGCGAAAGGCGGAA	ADCCUGAU
2274	UACADGUU	CUGAUGAGGCGAAAGGCGGAA	ACCGUCUC
2279	ACCCGUAU	CUGAUGAGGCGAAAGGCGGAA	ADCUUCC
2282	ACUCAUAU	CUGAUGAGGCGAAAGGCGGAA	AUAACUGU
2288	CAUUGGAG	CUGAUGAGGCGAAAGGCGGAA	ACCAGGCG
2291	GUAACTUG	CUGAUGAGGCGAAAGGCGGAA	AUAUCCCG
2321	ACCCGUAU	CUGAUGAGGCGAAAGGCGGAA	ADCUUCC
2338	CCUGUGGA	CUGAUGAGGCGAAAGGCGGAA	AAGCCAA
2339	GCCUGGGG	CUGAUGAGGCGAAAGGCGGAA	AAGUACCC
2341	UGAGCACG	CUGAUGAGGCGAAAGGCGGAA	ACAGGCC
2344	GAGAGGUC	CUGAUGAGGCGAAAGGCGGAA	ACGAGCAG
2358	UGUGGGAG	CUGAUGAGGCGAAAGGCGGAA	AGGCAGGG
2359	UUCUGUGG	CUGAUGAGGCGAAAGGCGGAA	ADGSAUGG
2360	CUUCCAGG	CUGAUGAGGCGAAAGGCGGAA	AACACAAAG
2376	AAGAGGAA	CUGAUGAGGCGAAAGGCGGAA	AGCAGUUC
2377	UAADAGAG	CUGAUGAGGCGAAAGGCGGAA	AGGAAGUC
2378	UCUGAAA	CUGAUGAGGCGAAAGGCGGAA	AAAUACAGC
2379	CGCAAGAG	CUGAUGAGGCGAAAGGCGGAA	AAGAGCAG
2380	ACUCUGGA	CUGAUGAGGCGAAAGGCGGAA	AGAAAUCA
2382	UGACUCGU	CUGAUGAGGCGAAAGGCGGAA	AAAGAAAU
2384	CUUGUGUC	CUGAUGAGGCGAAAGGCGGAA	ACCGGAUA
2399	CGUCCACA	CUGAUGAGGCGAAAGGCGGAA	AGUAUUA
2401	GAGGACCA	CUGAUGAGGCGAAAGGCGGAA	AUAGCACA
2411	UGAAGCAU	CUGAUGAGGCGAAAGGCGGAA	AGAAAUUG
2417	AACUUGUA	CUGAUGAGGCGAAAGGCGGAA	AUCCUGAU
2418	AGUUCUGU	CUGAUGAGGCGAAAGGCGGAA	AAGCAUGA
2425	GAACUCUG	CUGAUGAGGCGAAAGGCGGAA	AUUAADAA
2426	UAGUCUCC	CUGAUGAGGCGAAAGGCGGAA	ACCCAGGG
2433	AACUGUCA	CUGAUGAGGCGAAAGGCGGAA	AACUCUGA
2434	UUGUUGU	CUGAUGAGGCGAAAGGCGGAA	AUCUCUCC
2448	GGGGGAAG	CUGAUGAGGCGAAAGGCGGAA	ACUGUUCA
2449	CGAGGCAG	CUGAUGAGGCGAAAGGCGGAA	AAGGCUC
2451	GAGGCAGG	CUGAUGAGGCGAAAGGCGGAA	AACAGGCC
2452	AGAGGCAG	CUGAUGAGGCGAAAGGCGGAA	AAACAGGC
2455	AACAAAGG	CUGAUGAGGCGAAAGGCGGAA	AGGAADGU
2459	UGUGGGAG	CUGAUGAGGCGAAAGGCGGAA	AGGCAGGG
2460	UUGGGAAC	CUGAUGAGGCGAAAGGCGGAA	AAGGUAGG
2479	GGCGGUAA	CUGAUGAGGCGAAAGGCGGAA	AGGUGUAA
2480	GGGAUCAC	CUGAUGAGGCGAAAGGCGGAA	ACGGCGAC
2483	ACAUUGGG	CUGAUGAGGCGAAAGGCGGAA	ACAAAGGU
2484	GACAUUGG	CUGAUGAGGCGAAAGGCGGAA	AACAAAGG
2492	UAGGUGGG	CUGAUGAGGCGAAAGGCGGAA	AGGUGGUC

2504 UAGGAUUG CUGAUGAGGCGAAAGGCGGAA AUGUAGGU  
2508 AAGGUAGG CUGAUGAGGCGAAAGGCGGAA AUGUADGU  
2509 AAAGGUAG CUGAUGAGGCGAAAGGCGGAA AADGUADG  
2510 AADAGGUG CUGAUGAGGCGAAAGGCGGAA AAAUGGAC  
2520 ACAUUGGG CUGAUGAGGCGAAAGGCGGAA ACAAAAGGU  
2521 GACAUGGG CUGAUGAGGCGAAAGGCGGAA AACAAAGG  
2533 UGAGGGGU CUGAUGAGGCGAAAGGCGGAA AADGCGGU  
2540 GGAUACCU CUGAUGAGGCGAAAGGCGGAA AGCAACGA  
2545 AAAGUCCG CUGAUGAGGCGAAAGGCGGAA AGCUGCCU  
2568 CUGACACA CUGAUGAGGCGAAAGGCGGAA AADUCUG  
2579 CCAGGGCA CUGAUGAGGCGAAAGGCGGAA AGUGCAGG  
2585 GAGAGGUC CUGAUGAGGCGAAAGGCGGAA ACCAGCAG  
2588 GGCUGUGG CUGAUGAGGCGAAAGGCGGAA AGGAGGCA  
2591 CUUCGCAA CUGAUGAGGCGAAAGGCGGAA AGGAAGAG  
2593 AGCAGGGG CUGAUGAGGCGAAAGGCGGAA AADAGAGA  
2596 GCGACCAAG CUGAUGAGGCGAAAGGCGGAA ACCAGGAG  
2601 GAGGAACA CUGAUGAGGCGAAAGGCGGAA AUAGCAACA  
2602 ACAACGGC CUGAUGAGGCGAAAGGCGGAA ACCAGGAC  
2607 CCUGGUGA CUGAUGAGGCGAAAGGCGGAA ACUCCAC  
2608 UCCACCGG CUGAUGAGGCGAAAGGCGGAA AGCUAAAG  
2609 CAUCCAGU CUGAUGAGGCGAAAGGCGGAA AGUCUCCA  
2620 AACUGUCA CUGAUGAGGCGAAAGGCGGAA AACUCUGA  
2626 AGCAGCAC CUGAUGAGGCGAAAGGCGGAA ACUGAGAG  
2628 GGAGCGGA CUGAUGAGGCGAAAGGCGGAA AAGUUGUA  
2635 GUGAAUUG CUGAUGAGGCGAAAGGCGGAA AUCUGUGA  
2640 UGGAUUGA CUGAUGAGGCGAAAGGCGGAA ACCUGAGC  
2641 AADGUADG CUGAUGAGGCGAAAGGCGGAA AGGUGGGG  
2642 AGAGGCAG CUGAUGAGGCGAAAGGCGGAA AAACAGGC  
2653 AGCACCCU CUGAUGAGGCGAAAGGCGGAA AOCUGUGG  
2659 GCUUGCAG CUGAUGAGGCGAAAGGCGGAA AOCCTUCU  
2689 AGCUUCAG CUGAUGAGGCGAAAGGCGGAA AOCCTAGU  
2691 AGUCUCUC CUGAUGAGGCGAAAGGCGGAA AGGOCUGA  
2700 CCUGGGGG CUGAUGAGGCGAAAGGCGGAA AGUAACCU  
2704 UAGGUGGG CUGAUGAGGCGAAAGGCGGAA AGGUGGUC  
2711 ACCUUCU CUGAUGAGGCGAAAGGCGGAA AGGUAGGG  
2712 CACCUUCC CUGAUGAGGCGAAAGGCGGAA AAGGUAGG  
2721 AOCUGUAT CUGAUGAGGCGAAAGGCGGAA AUUUCUCC  
2724 CAAACCCG CUGAUGAGGCGAAAGGCGGAA AUGADCUU  
2744 CCUGCAAG CUGAUGAGGCGAAAGGCGGAA AUCCAACC  
2750 GGUUUUUA CUGAUGAGGCGAAAGGCGGAA ACAGGGAC  
2759 OCAUCUGA CUGAUGAGGCGAAAGGCGGAA AGUUCGUC  
2761 GGAAGAUC CUGAUGAGGCGAAAGGCGGAA AAAGUCCG  
2765 AGGCGGCA CUGAUGAGGCGAAAGGCGGAA AGCAAAAG  
2769 GCAGGGGU CUGAUGAGGCGAAAGGCGGAA AUAGAGAA  
2797 UUGACCAU CUGAUGAGGCGAAAGGCGGAA AUUUCACG  
2803 GUUCUGUG CUGAUGAGGCGAAAGGCGGAA AGCADGAG  
2804 AGUUCUGU CUGAUGAGGCGAAAGGCGGAA AAGCAUGA  
2813 AGGGUCAG CUGAUGAGGCGAAAGGCGGAA AUGGGAGC  
2815 GGAAGAUC CUGAUGAGGCGAAAGGCGGAA AAAGUCCG

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2821	ACCUCCAG	CUGAUGAGGCGAAAGGCGAA	AGGUCAGG
2822	GGAGCUGA	CUGAUGAGGCGAAAGGCGAA	AAGUUGUA
2823	UGGGAGCU	CUGAUGAGGCGAAAGGCGAA	AAAAGUUG
2829	GGAUACCU	CUGAUGAGGCGAAAGGCGAA	AGCACCGA
2837	GGGGGAAG	CUGAUGAGGCGAAAGGCGAA	ACCCUGUG
2840	UGCGCUGG	CUGAUGAGGCGAAAGGCGAA	AGGGGUGC
2847	AGGUGGGU	CUGAUGAGGCGAAAGGCGAA	AGGGGUA
2853	CUAGUCCG	CUGAUGAGGCGAAAGGCGAA	AGADCGAA
2860	UUCGAGGG	CUGAUGAGGCGAAAGGCGAA	ACACAGA
2872	UGAGCAC	CUGAUGAGGCGAAAGGCGAA	ACHGGCC
2877	GGGCGUGG	CUGAUGAGGCGAAAGGCGAA	AGACCCA
2899	AAAGUCCG	CUGAUGAGGCGAAAGGCGAA	AGGUGCCU
2900	AGAGAAGG	CUGAUGAGGCGAAAGGCGAA	AGUCAGCC
2904	AAGAGGAA	CUGAUGAGGCGAAAGGCGAA	AGCAGUUC
2905	AGAGAAGG	CUGAUGAGGCGAAAGGCGAA	AGUCAGCC
2906	UUAUAUAA	CUGAUGAGGCGAAAGGCGAA	ACACCAAC
2907	CGCAGAG	CUGAUGAGGCGAAAGGCGAA	AAGAGCAG
2908	AUUUAUA	CUGAUGAGGCGAAAGGCGAA	ADACACA
2909	AAGAGGAA	CUGAUGAGGCGAAAGGCGAA	AGCAGUUC
2910	GUAUAAGA	CUGAUGAGGCGAAAGGCGAA	AAGGAAGU
2911	GGGUAUA	CUGAUGAGGCGAAAGGCGAA	AGAAGGAA
2912	UGAAUUA	CUGAUGAGGCGAAAGGCGAA	AAAUACA
2913	CUGGGAAC	CUGAUGAGGCGAAAGGCGAA	AAUACACA
2914	UCUGAAU	CUGAUGAGGCGAAAGGCGAA	AUAUAUAC
2915	CUUCGAAU	CUGAUGAGGCGAAAGGCGAA	AUAUAUA
2916	CUUCGCAA	CUGAUGAGGCGAAAGGCGAA	AGGAAGAG
2917	GUCUUCGC	CUGAUGAGGCGAAAGGCGAA	AGAGGAAG
2918	UGACUCGU	CUGAUGAGGCGAAAGGCGAA	AAAGAAAU
2919	CAGUGGCU	CUGAUGAGGCGAAAGGCGAA	ACACAAA
2931	GGCAGCGG	CUGAUGAGGCGAAAGGCGAA	ACACCAUC
2933	GGGCGUGG	CUGAUGAGGCGAAAGGCGAA	AGACUCCA
2941	GCCUGGGG	CUGAUGAGGCGAAAGGCGAA	AAGUACCG
2951	GUCAGAGG	CUGAUGAGGCGAAAGGCGAA	AGCAUGGU
2952	GAAGAUCC	CUGAUGAGGCGAAAGGCGAA	AAGUCCCG
2955	CCAUGUCA	CUGAUGAGGCGAAAGGCGAA	AGGAAGCA
2956	AUUGAUTC	CUGAUGAGGCGAAAGGCGAA	AAGGAAG
2961	CAGUGGCU	CUGAUGAGGCGAAAGGCGAA	ACACAAA
2962	CUGGGAAC	CUGAUGAGGCGAAAGGCGAA	AAUACACA
2965	ACUUAU	CUGAUGAGGCGAAAGGCGAA	AUUCAAAG
2966	AGCUUGAA	CUGAUGAGGCGAAAGGCGAA	AGCUUCCA
2969	UAAACU	CUGAUGAGGCGAAAGGCGAA	AUUGAUTC
2975	AGCUUGAA	CUGAUGAGGCGAAAGGCGAA	AGCUUCCA
2976	CAGGUGAG	CUGAUGAGGCGAAAGGCGAA	ACCAUAUA
2977	UCAGCUUG	CUGAUGAGGCGAAAGGCGAA	AGAGCUUC

Table 11: Human IL-5 HH Target Sequence

nt. Position	HH Target Sequence	nt. Position	HH Target Sequence
8	ADGCACU U UC00UGC	245	AAGAAAU C UUUCAGG
9	UGCACUU U CU0UGCC	247	GAAAUUU U UCAGGGA
10	GCACUUU C UUUGCCA	248	AAAUUUU U CAGGGAA
12	ACUUUCU U UGCCAAA	249	AADCUUU C AGGGAAU
13	CUUUCUU U GOCAAAG	257	AGGGAAU A GGCACAC
36	AGAACGU U UCAGAGC	273	GGAGAGU C AAACUGU
37	GAACGUU U CAGAGCC	291	AGGGGGU A CUGUGGA
38	AAAGUUU C AGAGCCA	305	AAAGACU A UUCAAAA
56	GGADGCU U CUGCAUU	307	AGACUUA U CAAAAAC
57	GAUGCUU C UGCAUUU	308	GACUUAU C AAAAAAU
63	UCUGCAU U UGAGUUU	316	AAAAACU U GUCCUUA
64	CUGCAUU U GAGUUUG	319	AACUUGU C CUUAAUA
69	UUUGAGU U UGCUAGC	322	UUGUCCU U AAUAAAG
70	UUGAGUU U GCUAGCU	323	UGUCCUU A AUAAGA
74	GUUUGCU A GCUCUUG	326	CCUUAUU A AAGAAAU
78	GCUAGCU C UUGGAGC	334	AAGAAAU A CAUUGAC
80	UAGCUUU U GGAGCUG	338	AUAACAU U GACGGCC
91	GCUGCCU A CGUGUAU	380	GGAGAGU A AACCAAU
97	UACGGU A UGCCADC	388	AACCAAU U CCUAGAC
104	AUGCCAU C CCCACAG	389	ACCAAUU C CUAGACU
116	CAGAAAU U CCCACAA	392	AADUCCU A GACUACC
117	AGAAAUU C CCACAAG	397	CUAGACU A CCUGCAA
130	AGUGCAU U GGUGAAA	409	CAAGAGU U UC0UGGU
145	GAGACCU U GGCACUG	410	AAGAGUU U CUUGGUG
155	CACUGCU U UC0ACUC	411	AGAGUUU C UUGGUGU
156	ACUGCUU U CUACUCA	413	AGUUUCU U GGUGUAA
157	CUGCUUU C UACUCAU	419	UUGGUGU A AUGAACA
159	GCUUUCU A CUCAUUG	437	AGUGGAA A AUAGAAA
162	UUCUACU C AU0GAAC	440	GGAUAAU A GAAAGUU
165	UACUCAU C GAACUCU	447	AGAAAGU U GAGACUA
171	UCGAACU C UG0UGAU	454	UGAGACU A AACUGGU
179	UGCUGAU A G0CAAUG	462	AACUGGU U UGUUGCA
192	UGAGACU C UGAGGAU	463	ACUGGUU U GUUGCAG
200	UGAGGAU U CCUGUUC	466	GGUUUGU U GCA0CCA
201	GAGGAUU C CUGU0CC	479	CAAAGAU U UUGGAGG
206	UUCCUGU U CCUGUAC	480	AAAGAUU U UGGAGGA
207	UCCUGUU C CUGUACA	481	AAGAUUU U GGAGGAG
212	UUCUGU A CAUAAA	497	AGGACAU U UUA0UGC
216	UGUACAU A AAAAUCA	498	GGACAUU U UACUGCA
222	UAAAAAU C ACCAAAU	499	GACAUUU U ACUGCAG

500	ACAUUUU A CUGCAGU	684	UACUUUU U UCUUAUU
531	AAAGAGU C AGGCCUU	685	ACUUUUU U CUUAUUU
538	CAGGCCU U AAUUUUC	686	CUUUUUU C UUAUUUA
539	AGGCCUU A AUUUUCA	688	UUUUUUU U AUUUUAC
542	CCUUAAU U UUCAAUU	689	UUUUUUU A UUUAACU
543	CUUAUUU U UCAAUUU	691	UUCUUUU U UAAUUUA
544	UUAAUUU U CAUAUAU	692	UCUUUUU U AACUUUA
545	UAAUUUU C AAUAUAU	693	CUUAUUU A ACUUUAC
549	UUUCAAU A UAUAUAU	697	UUUAACU U AACAUUC
551	UCAAUUU A AUUAUAC	698	UUUAACU A ACUAUUC
554	AUAUAUU U UAACUUC	703	UUUAACU U CUGUAAA
555	UAUAUUU U AACUOCA	704	UAACAUU C UGUAAAA
556	AUAUUUU A ACUUCAG	708	AUUCUGU A AAAGUUC
560	UUUAACU U CAGAGGG	715	AAAAGUU C UGUUAAU
561	UUUAACU C AGAGGGA	719	UGUCUGU U AACUUUA
573	GGAAAGU A AAUAUUU	720	GUCUGUU A ACUUUAU
577	AGUAAAU A UUUCAGG	724	GUUAACU U AAUAUAU
579	UAAAUUU U UCAGGCA	725	UUUAACU A AUUAUAU
580	AAAUUUU U CAGGCAU	728	ACUUAAU A GUUAUUU
581	AAUAUUU C AGGCAUA	731	UAUAUAU A UUUAUUA
588	CAGGCAU A CUGACAC	733	AUAUAUU U UAUGAAA
597	UGACACU U UGCCAGA	734	UAUAUUU U AUGAAAU
598	GACACUU U GCCAGAA	735	AGUAUUU A UGAAAUU
611	AAAGCAU A AAUUUCU	745	AAAUUGU U AAGAUUU
616	AUAAAAU U CUAAAAA	746	AAUGGUU A AGAAUUU
617	UAAAAUU C UUAUAUU	752	UAAGAAU U UGGUAAA
619	AAAUUCU U AAAAUUU	753	AAGAAUU U GGUAAAU
620	AAUUCUU A AAUAUAU	757	AUUUGGU A AAUAUAU
625	UUAAAAU A UAUUUCA	761	GGUAAAU U AGUAUUU
627	AAAAUAU A UUUCAGA	762	GUAAAUU A GUUAUUU
629	AAUAUAU U UCAGAUU	765	AAUAUAU A UUUAUUU
630	AUAUAUU U CAGAUUU	767	UAUAUAU U UAUAUUU
631	UAUAUUU C AGAUUAU	768	UAUAUUU U AUUAUUU
636	UUCAGAU A UCAGAAU	769	AGUAUUU A UUUAUUU
638	CAGAUUU C AGAAUCA	771	UAUUUAU U UAAGUUU
644	UCAGAAU C AUUGAAG	772	AUUUAUU U AAUGUUU
647	GAAGCAU U GAAGUAU	773	UUUAUUU A AUUGUUU
653	UUGAAGU A UUUUCCU	778	UUUAUUU U AUUGUUU
655	GAAGUAU U UUCCUCC	779	UAAGUUU A UGUUGUG
656	AAGUAUU U UUCCUCC	783	GUUAUUU U GUGUUUU
657	AGUAUUU U CCUCCAG	788	GUUGUGU U CUUAUAU
658	GUUAUUU C CUCCAGG	789	UUUGUUU C UAUAUAU
661	UUUUCCU C CAGGCAA	791	GUGUUUU A AUAAAAU
672	GCAAAAU U GAUAUAU	794	UUUAUUU A AAACAAA
676	AAUUGAU A UAUUUUU	805	CAAAAAU A GACAACU
678	UUGAUUU A CUUUUUU		
581	AUAUAUU U UUUUUUU		
682	UAUAUUU U UUUCUUA		

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Table 12: Human IL-5 HH Ribozyme Sequences

nt. Position	HH Ribozyme Sequence
8	GCAAAGA CUGADGAGGCCGAAAGGCCGAA AGUGCAU
9	GGCAAAG CUGADGAGGCCGAAAGGCCGAA AAGUGCA
10	UGGCAAA CUGADGAGGCCGAAAGGCCGAA AAAGUGC
12	UUUGGCA CUGADGAGGCCGAAAGGCCGAA AGAAAGU
13	CUUUGGC CUGADGAGGCCGAAAGGCCGAA AAGAAAG
36	GCUCUGA CUGADGAGGCCGAAAGGCCGAA ACGUUCU
37	GGCUCUG CUGADGAGGCCGAAAGGCCGAA AACGUUC
38	UGGCUUC CUGADGAGGCCGAAAGGCCGAA AAAGGUU
56	AADGCAG CUGADGAGGCCGAAAGGCCGAA AGCAUCC
57	AAAGCA CUGADGAGGCCGAAAGGCCGAA AAGCAUC
63	AAACUCA CUGADGAGGCCGAAAGGCCGAA AUGCAGA
64	CAAACUC CUGADGAGGCCGAAAGGCCGAA AADGCAG
69	GUAGCA CUGADGAGGCCGAAAGGCCGAA ACUCAAA
70	AGCUAGC CUGADGAGGCCGAAAGGCCGAA AACUCAA
74	CAAGAGC CUGADGAGGCCGAAAGGCCGAA AGCAAAC
78	GCUCCAA CUGADGAGGCCGAAAGGCCGAA AGCUAGC
80	CAGCUCC CUGADGAGGCCGAAAGGCCGAA AGAGCUA
91	AUACACG CUGADGAGGCCGAAAGGCCGAA AGGCAGC
97	GAUGGCA CUGADGAGGCCGAAAGGCCGAA ACAGGUA
104	CUGUGG CUGADGAGGCCGAAAGGCCGAA ADGGCAU
116	UUGUGGG CUGADGAGGCCGAAAGGCCGAA AUUUCUG
117	CUUGGG CUGADGAGGCCGAAAGGCCGAA AAUUCU
130	UUUCACC CUGADGAGGCCGAAAGGCCGAA AUGCAU
145	CAGUGCC CUGADGAGGCCGAAAGGCCGAA AGGUCUC
155	GAGUAGA CUGADGAGGCCGAAAGGCCGAA AGCAGUG
156	UGAGUAG CUGADGAGGCCGAAAGGCCGAA AAGCAGU
157	AUGAGUA CUGADGAGGCCGAAAGGCCGAA AAAGCAG
159	CGADGAG CUGADGAGGCCGAAAGGCCGAA AGAAAGC
162	GUUCGAU CUGADGAGGCCGAAAGGCCGAA AGUAGAA
165	AGAGUUC CUGADGAGGCCGAAAGGCCGAA AUGAGUA
171	AUCAGCA CUGADGAGGCCGAAAGGCCGAA AGUUGA
179	CAUUGGC CUGADGAGGCCGAAAGGCCGAA AUCAGCA
192	AUCCUCA CUGADGAGGCCGAAAGGCCGAA AGUCUCA
200	GAACAGG CUGADGAGGCCGAAAGGCCGAA AUCCUCA
201	GGAACAG CUGADGAGGCCGAAAGGCCGAA AUCCUC
206	GUACAGG CUGADGAGGCCGAAAGGCCGAA ACAGGAA
207	UGUACAG CUGADGAGGCCGAAAGGCCGAA AACAGGA
212	UUUUAUG CUGADGAGGCCGAAAGGCCGAA ACAGGAA
216	UGAUUUU CUGADGAGGCCGAAAGGCCGAA AUGUACA
222	AGUUGGU CUGADGAGGCCGAAAGGCCGAA AUUUUA
245	CCUGAAA CUGADGAGGCCGAAAGGCCGAA AUUUCU

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247	UCCOCUGA	CUGAUGAGGCCGAAAGGCCGAA	AGAUUUC
248	UCCOCUG	CUGAUGAGGCCGAAAGGCCGAA	AAGAUUU
249	AUCCOCU	CUGAUGAGGCCGAAAGGCCGAA	AAAGAUU
257	GUGUGCC	CUGAUGAGGCCGAAAGGCCGAA	AUCCCUU
273	ACAGUUU	CUGAUGAGGCCGAAAGGCCGAA	ACUCUCC
291	UCCACAG	CUGAUGAGGCCGAAAGGCCGAA	ACCCOCU
305	UUUUGAA	CUGAUGAGGCCGAAAGGCCGAA	AGUCUUU
307	GUUUUG	CUGAUGAGGCCGAAAGGCCGAA	AUAGUCU
308	AGUUUUU	CUGAUGAGGCCGAAAGGCCGAA	AAUAGUC
316	UAAGGAC	CUGAUGAGGCCGAAAGGCCGAA	AGUUUUU
319	UAUAAG	CUGAUGAGGCCGAAAGGCCGAA	ACAAGUU
322	CUUUAUU	CUGAUGAGGCCGAAAGGCCGAA	AGGACAA
323	UCUUUAU	CUGAUGAGGCCGAAAGGCCGAA	AAGGACA
326	AUUUCUU	CUGAUGAGGCCGAAAGGCCGAA	AUUAAAG
334	GCCAADG	CUGAUGAGGCCGAAAGGCCGAA	AUUUCUU
338	GGCUGUC	CUGAUGAGGCCGAAAGGCCGAA	AUGUAUU
380	AUUGGUU	CUGAUGAGGCCGAAAGGCCGAA	ACUCUCC
388	GUCUAGG	CUGAUGAGGCCGAAAGGCCGAA	AUUGGUU
389	AGUCUAG	CUGAUGAGGCCGAAAGGCCGAA	AUUGGUU
392	GGUAGUC	CUGAUGAGGCCGAAAGGCCGAA	AGGAUUU
397	UUGCAGG	CUGAUGAGGCCGAAAGGCCGAA	AGUCUAG
409	ACCAAGA	CUGAUGAGGCCGAAAGGCCGAA	ACUCUUG
410	CACCAAG	CUGAUGAGGCCGAAAGGCCGAA	AACUCUU
411	ACAACCA	CUGAUGAGGCCGAAAGGCCGAA	AAACUCU
413	UUAACAC	CUGAUGAGGCCGAAAGGCCGAA	AGAAACU
419	UGUUCAU	CUGAUGAGGCCGAAAGGCCGAA	ACACCAA
437	UUUCUUA	CUGAUGAGGCCGAAAGGCCGAA	AUCCACU
440	AACUUUC	CUGAUGAGGCCGAAAGGCCGAA	AUUUUCU
447	UAGUCUC	CUGAUGAGGCCGAAAGGCCGAA	ACUUUCU
454	ACCAGUU	CUGAUGAGGCCGAAAGGCCGAA	AGUCUCA
462	UGCAACA	CUGAUGAGGCCGAAAGGCCGAA	ACCAGUU
463	CUGCAAC	CUGAUGAGGCCGAAAGGCCGAA	AACCAGU
466	UGGCUUC	CUGAUGAGGCCGAAAGGCCGAA	ACAAACC
479	CCUCCAA	CUGAUGAGGCCGAAAGGCCGAA	AUCUUUG
480	UCCUCCA	CUGAUGAGGCCGAAAGGCCGAA	AADCUUU
481	CUUCUCC	CUGAUGAGGCCGAAAGGCCGAA	AAAUUUU
497	GCAGUAA	CUGAUGAGGCCGAAAGGCCGAA	AUGUCCU
498	UGCAGUA	CUGAUGAGGCCGAAAGGCCGAA	AADGUCC
499	CUGCAGU	CUGAUGAGGCCGAAAGGCCGAA	AAADGUC
500	ACUGCAG	CUGAUGAGGCCGAAAGGCCGAA	AAAADGU
531	AAGGOCU	CUGAUGAGGCCGAAAGGCCGAA	ACUCUUU
538	GAAAAUU	CUGAUGAGGCCGAAAGGCCGAA	AGGCCUG
539	UGAAAAU	CUGAUGAGGCCGAAAGGCCGAA	AAGGCCU
542	UAUUGAA	CUGAUGAGGCCGAAAGGCCGAA	AUUUAGG
543	AUAUUGA	CUGAUGAGGCCGAAAGGCCGAA	AADUAAG
544	UAUAUUG	CUGAUGAGGCCGAAAGGCCGAA	AAAUUAA
545	UUAUAUU	CUGAUGAGGCCGAAAGGCCGAA	AAAAUUA
549	UAAAUUA	CUGAUGAGGCCGAAAGGCCGAA	AUUGAAA
551	GUUAAAU	CUGAUGAGGCCGAAAGGCCGAA	AUAUUGA

554	GAAGUUA	CUGADGAGGCGAAAGGCCGAA	AUUUAUAU
555	UGAAGUU	CUGADGAGGCGAAAGGCCGAA	AAUUAUA
556	CUGAAGU	CUGADGAGGCGAAAGGCCGAA	AAAUUAU
560	CCCUUCU	CUGADGAGGCGAAAGGCCGAA	AGUUAUA
561	UCCUCU	CUGADGAGGCGAAAGGCCGAA	AAGUUAU
573	AAAUUAU	CUGADGAGGCGAAAGGCCGAA	ACUUUCC
577	CCUGAAA	CUGADGAGGCGAAAGGCCGAA	AUUUAU
579	UGCCUGA	CUGADGAGGCGAAAGGCCGAA	AUAUUUA
580	AUGCCUG	CUGADGAGGCGAAAGGCCGAA	AAUAUUU
581	UAUGCCU	CUGADGAGGCGAAAGGCCGAA	AAAUUAU
588	GUGUCAG	CUGADGAGGCGAAAGGCCGAA	AUGCCUG
597	UCUGGCA	CUGADGAGGCGAAAGGCCGAA	AGUGUCA
598	UUCUGGC	CUGADGAGGCGAAAGGCCGAA	AAGUGUC
611	AGAAUUU	CUGADGAGGCGAAAGGCCGAA	AUGCUUU
616	UUUUUAG	CUGADGAGGCGAAAGGCCGAA	AUUUUUU
617	AUUUUAA	CUGADGAGGCGAAAGGCCGAA	AAUUUUA
619	AUAUUUU	CUGADGAGGCGAAAGGCCGAA	AGAAUUU
620	UAUAUUU	CUGADGAGGCGAAAGGCCGAA	AAGAAUU
625	UGAAUUA	CUGADGAGGCGAAAGGCCGAA	AUUUUUA
627	UCUGAAA	CUGADGAGGCGAAAGGCCGAA	AUAUUUU
629	UAUCUGA	CUGADGAGGCGAAAGGCCGAA	AUAUAUU
630	AUAUCUG	CUGADGAGGCGAAAGGCCGAA	AAUAUAU
631	GUAUUCU	CUGADGAGGCGAAAGGCCGAA	AAAUUAU
636	AUUCUGA	CUGADGAGGCGAAAGGCCGAA	AUCUGAA
638	UGAUUCU	CUGADGAGGCGAAAGGCCGAA	AUAUCUG
644	CUUCAAU	CUGADGAGGCGAAAGGCCGAA	AUUCUGA
647	AUAUCUC	CUGADGAGGCGAAAGGCCGAA	AUGAUUC
653	AGGAAAA	CUGADGAGGCGAAAGGCCGAA	ACTUCAA
655	GGAGGAA	CUGADGAGGCGAAAGGCCGAA	AUAUCUC
656	UGGAGGA	CUGADGAGGCGAAAGGCCGAA	AAUAUCU
657	CUGGAGG	CUGADGAGGCGAAAGGCCGAA	AAAUACT
658	CCUGGAG	CUGADGAGGCGAAAGGCCGAA	AAAUUAC
661	UUGCCUG	CUGADGAGGCGAAAGGCCGAA	AGEAAAA
672	GUUAUUC	CUGADGAGGCGAAAGGCCGAA	AUUUUGC
676	AAAAGUA	CUGADGAGGCGAAAGGCCGAA	AUCAAUU
678	AAAAAAG	CUGADGAGGCGAAAGGCCGAA	AUAUCAA
681	AAGAAAA	CUGADGAGGCGAAAGGCCGAA	AGUAUAU
682	UAAGAAA	CUGADGAGGCGAAAGGCCGAA	AAGUAUA
683	AUAAGAA	CUGADGAGGCGAAAGGCCGAA	AAAGUAU
684	AAUAAGA	CUGADGAGGCGAAAGGCCGAA	AAAAGUA
685	AAAUUAG	CUGADGAGGCGAAAGGCCGAA	AAAAAGU
686	UAAAUAA	CUGADGAGGCGAAAGGCCGAA	AAAAAAG
688	GUUAAAU	CUGADGAGGCGAAAGGCCGAA	AGAAAAA
689	AGUAAAA	CUGADGAGGCGAAAGGCCGAA	AAGAAAA
691	UAAGUUA	CUGADGAGGCGAAAGGCCGAA	AUAAGAA
692	UUAAGUU	CUGADGAGGCGAAAGGCCGAA	AAUAAGA
693	GUUAGUU	CUGADGAGGCGAAAGGCCGAA	AAAUUAG
697	GAAUGUU	CUGADGAGGCGAAAGGCCGAA	AGUUAUA
698	AGAAUGU	CUGADGAGGCGAAAGGCCGAA	AAGUUAU

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703	UUUACAG	CUGAUGAGGCGAAAGGCGGAA	AUGUUAA
704	UUUACA	CUGAUGAGGCGAAAGGCGGAA	AADGUUA
708	GACAUUU	CUGAUGAGGCGAAAGGCGGAA	ACAGAAU
715	GUUACA	CUGAUGAGGCGAAAGGCGGAA	ACAUUUU
719	UUAGUU	CUGAUGAGGCGAAAGGCGGAA	ACAGACA
720	AUUAGU	CUGAUGAGGCGAAAGGCGGAA	AACAGAC
724	UAUAUU	CUGAUGAGGCGAAAGGCGGAA	AGUUUAC
725	AUAUAU	CUGAUGAGGCGAAAGGCGGAA	AAGUUAA
728	UAAUAU	CUGAUGAGGCGAAAGGCGGAA	AUUAAGU
731	UCAAUA	CUGAUGAGGCGAAAGGCGGAA	ACUAUUA
733	UUUCAUA	CUGAUGAGGCGAAAGGCGGAA	AUAUAU
734	AGUUCAU	CUGAUGAGGCGAAAGGCGGAA	AUAUAU
735	CAUUUA	CUGAUGAGGCGAAAGGCGGAA	AAUAUAU
745	AAUUCUU	CUGAUGAGGCGAAAGGCGGAA	ACCAUUU
746	AAAUUCU	CUGAUGAGGCGAAAGGCGGAA	ACCAUUU
752	UUUACCA	CUGAUGAGGCGAAAGGCGGAA	AUUUUUA
753	AUUUACC	CUGAUGAGGCGAAAGGCGGAA	AAUUCUU
757	ACUAUUU	CUGAUGAGGCGAAAGGCGGAA	ACCAAUU
761	AAUAUAU	CUGAUGAGGCGAAAGGCGGAA	AUUUACC
762	UAAUAU	CUGAUGAGGCGAAAGGCGGAA	AUUUUAU
765	AAUAUAU	CUGAUGAGGCGAAAGGCGGAA	ACUAUUU
767	UUAAUA	CUGAUGAGGCGAAAGGCGGAA	AUAUAU
768	AUUAAU	CUGAUGAGGCGAAAGGCGGAA	AAUAUAU
769	CAUUAU	CUGAUGAGGCGAAAGGCGGAA	AAUAUAU
771	AAUAUA	CUGAUGAGGCGAAAGGCGGAA	AAUAUAU
772	UAUAUA	CUGAUGAGGCGAAAGGCGGAA	AAUAUAU
773	AUAUAU	CUGAUGAGGCGAAAGGCGGAA	AAUAUAU
778	ACAUAU	CUGAUGAGGCGAAAGGCGGAA	ACAUAUA
779	CACAUA	CUGAUGAGGCGAAAGGCGGAA	ACAUAUA
783	AGAUAU	CUGAUGAGGCGAAAGGCGGAA	ACAUAUA
788	UUUAUA	CUGAUGAGGCGAAAGGCGGAA	ACAUAUA
789	UUUAUA	CUGAUGAGGCGAAAGGCGGAA	ACAUAUA
791	GUUUUA	CUGAUGAGGCGAAAGGCGGAA	AGAUAUA
794	UUUGUU	CUGAUGAGGCGAAAGGCGGAA	AUUUAUA
805	AGUUUG	CUGAUGAGGCGAAAGGCGGAA	AUUUUUA

Table 13: Mouse IL-5 HH Ribozyme Target Sequence

nt. Position	HH Target Sequence	nt. Position	HH Target Sequence
8	cGcUcUU c CUUUGCu	253	AGGGgcU A GaCaAAC
11	uCUUcCU U UGcUGAA	259	UagACAU a CUgAGaA
12	CUUcCUU U GCUgAAG	269	GeAGaaU C AAAcUGU
36	GAAgacU U CAGAGuC	269	GaAGaaU c AAaCugU
36	GaAgAcU u cAgAGUc	269	GAgaAU c aAaCugU
37	AAgaCUU C AGAGuCA	287	uGGGGGU A CUUGGA
43	UcaGaGU c AUGAgaA	301	AAAugCU A UUCcAAA
58	GGAUGCU U CUGCacU	301	AAAugCU a uUCCaaA
59	GADGCUU C UGCacUU	303	AUGCUAU u CCaAaAc
59	gADGcUU c uGcAcUU	303	AugCUAU U CcAAAAc
66	CUGCAcU U GAGUgUu	304	ugCUAUU C cAAAAcC
82	UgAcucU c aGcUGUG	315	AAcCUGU C aUUAUA
91	GcUgUGU c uggGCCA	318	cUGUCaU U AAUAAG
112	ugGAgAU U CCCAugA	319	UGUCaUU A AUAAAGA
113	gGAgAUU C CCAugAG	322	CaUUAUU A AAGAAAU
141	GAGACCU U GaCACaG	330	AAAGAAU A CAUGAC
141	GAgACcU U GaCAcAg	334	AAUACAU U GACcGCC
158	gUCCgCU C AcCGAgC	334	AAUaCaU u GACcGCC
167	cCGAgCU C UGUUGAc	384	AggCAgU U CUgGAu
196	UGAGGcU U CUUGUcC	385	ggCAgUU C CUgGAuU
197	GAGGcUU C CUGUcCC	393	CUgGAuU A CCUGCA
197	gAGGCUU c CUGUcCC	405	CAAGAGU U cCUUGGU
202	UUCCUGU c CCUacuc	406	AAAGAGU c CUUGGUG
202	UUCCUGU c CcUacuc	409	AGUUCU U GUGUGa
206	UGUCcU a cuCaUAA	481	UcCaAUU u UAAgUUA
212	UACUCAU a aAAaUCA	482	cAaAAUU U AAgUUaA
212	UacuCAU A AAAAUCA	483	AcaAUUU A AgUUaAa
218	UaaAaaU c aCcAGCU	483	AcaAUUU a aGUUAaA
218	UAAAAAU C ACCAgCU	495	AAAUUGU c AAcAgAU
218	uAAAAAU c acCAgCU	553	GCUGuuU c CaDuUAU
232	uaUGCAU U GGAaGAA	557	UuUcCAU U UauaUUU
241	gAGAAAU C UUUCAGG	564	UUeuAUU u aUgUCCU
241	gAgAaAU c UUucAGG	564	UUauaUU u AugUcCU
241	gagAAAU c UUUCAGG	565	uaUAUUU a ugUCCuG
241	gAgAaAU c UUUCAGg	565	UAUAUUU a UgUCCUg
243	gaAAucU U UCAGgGg	569	UUuADGU c cUGUaGU
243	GAAAUcU U UCAGGGg	569	uUUUAUGU c cUGUaGU
244	AAAUcUU U CAGGGgc	613	AAAGuGU u uzaCCUU
245	AAUcUUU C AGGGgcU	614	AAgUGuU u aAcCUUU

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620	UUAACcU u uDuGUU	1407	cCagUUU A CUcCAGg
793	caAGgCU u UGuGcAU	1407	ccAgUUU a CUCCAGG
816	CUGagUU a UACUCcc	1410	gUUUaCU C CAGGaAA
818	GAgUUAU a cUCCcuC	1434	ADgCUUU U aUuUaAU
825	ACUcCcu c CccCUCA	1434	aUgcUuU U AUUUAAu
825	aCUccCU c CccCUCa	1434	aUgcUuU u AuUUAAU
839	AuCUcUcU U cGUUGCA	1435	UgCUUUU a UuUaAUU
840	uCcucUU c GUUGCAu	1435	ugcUUUU a uUUaAUU
863	cAAgUAU U cCAGGCU	1438	UuUUAGU U AAuUcug
864	AAgUAU c CAGGCUg	1438	uUUUAUU U AAUucUg
864	AAgUAU c caggCUg	1439	UUUAUUU A AUucUgU
913	gAaCUUcU U GUcCaG	1443	UUUaAuU c UGuaAGa
917	UcUuggU c CAGAuGG	1447	AUUCUGU A AgAUcUu
957	UUagcAU c CUUcUc	1458	ugUUcaU a UUAUUUA
960	GCAuccU u UcUcCUA	1458	ugUUcAU A uUAUUUA
960	GcaUcCU u uCUcCUa	1460	UucAUU u AUUUAug
962	AUcCUuU c UCcUaGC	1461	UcAUUuU A UUUUUGA
975	gccccCUU u AgAUAGa	1463	AUAUUUU U UADGAug
987	aGaUGAU A cuuAAUG	1475	AuGgAUU c aGUAAgU
990	UGAuACU u AAuagcU	1479	AUUcaGU A AgUUUAU
1000	UGACUcU c UugCUGA	1483	aGuAAGU u AAUAUUU
1027	CgggGCU U cCUgCUC	1483	aGUAAgU U AaUAUUU
1034	UCCCGcU C CUaUcuA	1484	GUAAgUU A aUAUUUA
1037	UgcUCCU A UcUAACU	1487	agUUAAU a UUUuAUU
1039	cUccuAU c UAACUUC	1487	AgUUAAU A UUUUAUU
1039	cUCCUAU c UAACUUC	1489	UUAAUuU U uAuUAca
1041	CcUAUcU A ACUUCaA	1489	UUAAuAU u UAUUaCA
1051	UUcAAuU U AAuAccC	1489	UUaUAU U UAUUaCA
1148	uGAcUUU u cUuaUGU	1490	UAUAUuU u AuUAcAc
1213	GCUGGaU u UUGGAaa	1490	UAaUAUU U AUUAcAc
1213	gcUGGAU u uUgGAAA	1490	UAaUAUU U AUUAcAc
1214	cugGAUU U UGGAAaA	1491	AAUAUUU a uuacAcg
1215	ugGAUUU U GGAaaAG	1491	AAUAUUU a UuAcAcg
1234	gGGACAU c UccuUGC	1491	AaUAUUU A UuAcAcG
1236	GACAUcU c cuUGCAG	1491	AaUAUUU A UUAcaCG
1275	ugGGCCU U AcUUcUC	1494	AUUUAUU a CAcgUAU
1276	gGGCCUU A cUUcUCC	1502	cACGUaU A UaauAUu
1280	CUUAcUU c UCcgUgU	1502	cAcgUAU a UUAUaUU
1298	UgAACUU a AGAaGcA	1507	AUAUAaU a UUCUaaU
1310	gcAAAGU a aAuACcA	1509	AUAuuAU U CUaAuAA
1310	GCAAAgU a aAUAcca	1509	aUaaUaU U CUAADUA
1310	GcaAAgU a AAUAcca	1510	UAuuAUU C UaauAAA
1350	AAAGCAU A AAUggU	1510	UAuuAUU c UaaUAAA
1358	AAADGGU U ggGAugU	1510	UAuuAUU c UaaUAAA
1370	UgUuaUU C AGGUUUC	1510	UaaUaUU C UAUAUAA
1375	UUCAGgU A UCAGggU	1512	aUaUUUU A AUAAAgC
1377	CAGGUUU C AGggUCA	1515	UUUUAAU A AAgCAgA
1383	UCAGggU C AcUGgAG		
1405	cccCAgU U UACUcCA		

Table 14: Human IL-5 Hairpin Ribozyme Sequences

nt. Position	Hairpin Ribozyme Sequence	Substrate
86	UACACGUA AGAA GGUCCA ACCAGACAAACACAGUGUGUGUACAUUACUUGUA	UGGACU GGC UACGUGUA
151	GAGUAGAA AGAA GGUCCA ACCAGACAAACACAGUGUGUGUACAUUACUUGUA	UGGACU GGU UUGUACUC
172	UGGCUAUC AGAA GAGUUC ACCAGACAAACACAGUGUGUGUACAUUACUUGUA	GACUUC GGU GAUAGCCA
203	UGUACAGG AGAA GGAUUC ACCAGACAAACACAGUGUGUGUACAUUACUUGUA	GAUUCU GGU CUUGUACA

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Table 15: Mouse IL-5 Hairpin Ribozyme Sequences

nt. Position	Hairpin Ribozyme Sequence	Substrate
75	AGCUGAGA AGAA GAACAC ACCAGAGAACACACGUGUGUGGUCACUUAUACUUGUA	GUGUUC GAC UCUAGCU
83	CCAGACAC AGAA GAGGUG ACCAGAGAACACACGUGUGUGGUCACUUAUACUUGUA	ACUUCU GCU GUGUUGG
147	GAGCGCAC AGAA GUGUCA ACCAGAGAACACACGUGUGUGGUCACUUAUACUUGUA	UGACACA GCU GUGCGUC
150	GUGCGCG AGAA GUGUG ACCAGAGAACACACGUGUGUGGUCACUUAUACUUGUA	CACGCU GCU GCGUACG
154	GUUGGUG AGAA GACGCG ACCAGAGAACACACGUGUGUGGUCACUUAUACUUGUA	GUGUUC GCU CACCGAGC
168	UGUGUGG AGAA GAGCUC ACCAGAGAACACACGUGUGUGGUCACUUAUACUUGUA	GAGCUC GUU GACAGACA
199	UGGUGUG AGAA GCGAGC ACCAGAGAACACACGUGUGUGGUCACUUAUACUUGUA	GUUUCU GUC CUUACUCA
274	CCCCGCG AGAA GUUUGA ACCAGAGAACACACGUGUGUGGUCACUUAUACUUGUA	UCAAACU GUC GUGGGGG
381	AAUCCAG AGAA GCUUG ACCAGAGAACACACGUGUGUGGUCACUUAUACUUGUA	CGAGCA GUU CUUGAUU
454	CACCAUG AGAA GCUUAG ACCAGAGAACACACGUGUGUGGUCACUUAUACUUGUA	CUAGCU GCU CCUUGGUG
499	GUUUUG AGAA GUUGAC ACCAGAGAACACACGUGUGUGGUCACUUAUACUUGUA	GUCACA GAU GCAAAAC
548	UAAUUGA AGAA GCAUUA ACCAGAGAACACACGUGUGUGGUCACUUAUACUUGUA	AUUCU GUU UCCAUUA
701	GCAGGAG AGAA GAAUU ACCAGAGAACACACGUGUGUGGUCACUUAUACUUGUA	AUUUU GAU CUUUUCC
710	GAGAGGA AGAA GCGGGA ACCAGAGAACACACGUGUGUGGUCACUUAUACUUGUA	UCCUUU GGC UCCUUUC
870	AGUUCAA AGAA GCGUCA ACCAGAGAACACACGUGUGUGGUCACUUAUACUUGUA	CCAGCU GAC UUGNACU
919	CUUGUUC AGAA GCGAGC ACCAGAGAACACACGUGUGUGGUCACUUAUACUUGUA	UGUCCA GAU GCGCCAG
1030	UAGAUAG AGAA GCGAGC ACCAGAGAACACACGUGUGUGGUCACUUAUACUUGUA	GUUUUU GCU CCUUAUCU
1170	AUGGACA AGAA GAUACA ACCAGAGAACACACGUGUGUGGUCACUUAUACUUGUA	UGAUCA GAC UGUGCCAU
1205	CAAAUUC AGAA GUUCCA ACCAGAGAACACACGUGUGUGGUCACUUAUACUUGUA	UGAGCA GCU GGAUUUG
1402	CUUGAGU AGAA GCGGGA ACCAGAGAACACACGUGUGUGGUCACUUAUACUUGUA	UCCUCCA GUU UACUCCAG
1421	AGCAUAC AGAA GUUUUU ACCAGAGAACACACGUGUGUGGUCACUUAUACUUGUA	AAAUACA GAU GUNUCCU

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Table 16 : Mouse IL-5 Hairpin Ribozyme Sequences

nt. Position	Hairpin Ribozyme Sequence	Substrate
75	AGCUGAGA AGAA GACAC ACCAGAGAACACAGUUGUGGUCACUUPACUUGUA	GUGUUU GAC UCUAGCU
83	CCAGACAC AGAA GAGGU ACCAGAGAACACAGUUGUGGUCACUUPACUUGUA	ACUUCU GCU GUUUGUG
147	GAGCGAC AGAA GUUUA ACCAGAGAACACAGUUGUGGUCACUUPACUUGUA	UGACACA GCU GUUGGUC
150	GGUGGG AGAA GCUUG ACCAGAGAACACAGUUGUGGUCACUUPACUUGUA	CACAGCU GUC GGUUAC
154	GUUGGG AGAA GACAC ACCAGAGAACACAGUUGUGGUCACUUPACUUGUA	GUUGUC GCU CACAGAC
168	UCUUGUC AGAA GUGUC ACCAGAGAACACAGUUGUGGUCACUUPACUUGUA	GAGUUU GCU GACAGCA
199	UGAGUGG AGAA GAGGC ACCAGAGAACACAGUUGUGGUCACUUPACUUGUA	GUUUUU GUC GUUUCUA
274	CCCCACG AGAA GUUGA ACCAGAGAACACAGUUGUGGUCACUUPACUUGUA	UCAAAU GUC GGUUGGG
381	AUUCAGG AGAA GCUUG ACCAGAGAACACAGUUGUGGUCACUUPACUUGUA	CGAGCA GCU CUUGGUA
454	CACUUGG AGAA GCUUG ACCAGAGAACACAGUUGUGGUCACUUPACUUGUA	CUAGCU GCU CCAUGGG
499	GUUUUGG AGAA GUUAC ACCAGAGAACACAGUUGUGGUCACUUPACUUGUA	GUACACA GAU GCAAAAC
548	UAAUUGG AGAA GCANU ACCAGAGAACACAGUUGUGGUCACUUPACUUGUA	AAUUGU GCU UCUUUUA
701	GCAGGAG AGAA GAAUU ACCAGAGAACACAGUUGUGGUCACUUPACUUGUA	AAUUUU GAU CUUUUUC
710	GAGAGGA AGAA GAGGA ACCAGAGAACACAGUUGUGGUCACUUPACUUGUA	UUUUUU GGC UCUUUUC
870	AGUUCAA AGAA GCUUG ACCAGAGAACACAGUUGUGGUCACUUPACUUGUA	CCAGCU GAC UUGAAAU
919	CUUGUUC AGAA GGUCA ACCAGAGAACACAGUUGUGGUCACUUPACUUGUA	UGGUCA GAU GCAUGG
1030	UGAUUGG AGAA GAGGC ACCAGAGAACACAGUUGUGGUCACUUPACUUGUA	GUUUUU GCU CUUUUUA
1170	AUGGACA AGAA GAUUA ACCAGAGAACACAGUUGUGGUCACUUPACUUGUA	UGAAUA GAC UGUUUUU
1205	CAAAUUC AGAA GCUUA ACCAGAGAACACAGUUGUGGUCACUUPACUUGUA	UGAGCA GCU GCAUUUG
1402	CUAGGUA AGAA GGGGA ACCAGAGAACACAGUUGUGGUCACUUPACUUGUA	UUUUUU GCU UGCUUUG
1421	AACAUAC AGAA GUUUU ACCAGAGAACACAGUUGUGGUCACUUPACUUGUA	AAAAAA GAU GUUUUU



Table 17

Mouse ref A HH Target sequence

nt. Position HH Target Sequence nt. Position HH Target Sequence

19	AADGGCU a caCaGgA	467	cCAGGCU c cuguUCg
22	aGCUcCU a cGUgGCG	469	ΔΔGCcAU u ΔGcCAGC
26	CcUCCaU u GcGgACa	473	UuUgAGU C ΔGauCAG
93	GAuCUGU U uCCCCUC	481	ΔGCGaAU C CAGACCA
94	ΔuCUGUU u CCCCUCA	501	ΔACCCCU U uCAcGUU
100	UuCCCCU C ΔUCUUC	502	ΔCCCCU u CAcGUUC
103	CCCUCAU C UuCCcA	508	UuCAcGU U CCUAUAG
105	CUCAUCU U uCCcUA	509	uCAcGUU C CUUAAGA
106	UCAUCU u CCcUcAG	512	cGUUCCU A UAGAgGA
129	CAGGCUU C UGGgCCu	514	UGCCUAU A GAgGAGC
138	GGgCCuU A UGUgGAG	534	GGGGAU A uGAUUG
148	UGGAGAU C AUcGAaC	556	UGGcCU C UGUUUC
151	AGAUCAU c GAaCAGC	561	CUUGCU U CCAGGUG
180	AUGGGAU U CCGCUAU	562	UCUGCU C CAGGUGA
181	UGGGAU C CGCUAU	585	aAgCCAU u AGcCAGc
186	UUCCGCU A uAAaUGC	598	GGCCCU C CuCCUGa
204	GGGGCU C aGGGGC	613	CcCCUGU C CUcCaC
217	GCAGAUU u CUgGGG	616	CGUCCU c uCaCADC
239	CACAGAU A CCAcCA	617	guCCCU C CUcAgCC
262	CCACAU C AAGAUA	620	CCUCCU C ΔgCCaug
268	UCAAGAU C AADGGCU	623	UCCUGcU u CCAUCUc
276	ΔAUGGCU A CACAGGA	628	ΔUCCgAU u UUUGAU
301	UuCCGAU u UCCUGG	630	CCgAUuU U UGAuAAc
303	CGAUUCU C CCUGGUC	631	CgAUuU U GAuAAcC
310	CCCUGGU C ACCAAGG	638	UGgCcAU u GGUuCC
323	GGcCCU C CUcCuga	661	CCGAGCU C ΔAGAUCU
326	uCCaCCU C ACCGGCC	667	UCAAGAU C UGCcGAG
335	CCGGCCU C AuCCaCA	687	CGgAACTU C UGGgAGC
349	ΔuGAaCU U GUgGGgA	700	GCUGCCU C GGUgGGG
352	AGAUCaU c GAaCAGc	715	AUGAGAU C UUCuUgC
375	GAUGGCU a CUUAUGAG	717	GAGAUUCU U CuUgCUG
376	AUGGUCU C UccGgaG	718	AGAUCU C uUgCUGU
378	GGCUaCU A UGAGGCU	721	UucUCCU c CAuUGcG
391	CUGAcCU C UGOCaG	751	ΔaGACAU U GAGGUU
409	GCaGAU C CAuAGcU	759	GAGGUU A UUUCACG
416	CCgCAGU a UCCAuAg	761	GGUGUAU U UCAcGGG
417	CAuAGcU U CCAGAAC	762	GUUAUU U CAcGGGA
418	AuAGcUU C CAGAAC	763	UGUAUU C ACcGGAC
433	UGGGgAU C CAGUGUG	792	CGAGGCU C CUUUUCu
795	GGCUCCU U UUCuCAA	1167	GAUGAGU U UuCCcCC
796	GCUCCU U UCuCAAG	1168	ΔUGAGUU U uCCcCCA
797	CUCCUUU U CuCAAGC	1169	UGAGUUU u CCcCAU
798	UCCUUUU C uCAAGCU	1182	ΔUGcUGU U ΔCCaUCA
829	UGGCCAU U GUGUUCC	1183	UGcUGUU a CCaUCAg

834	AUUGUGU U	COGACu	1184	GGccccU C	CUcCUGa
835	UUGUGUU C	CGGACuC	1187	GUccCuU c	CUcaGCc
845	GACuCCU C	CgUACGC	1188	UUaCCaU C	aGGGCAG
849	CCUCCgU A	CGCcGAC	1198	GGgAGuU u	AGuCuGa
872	cCAGGCU C	CUGuucG	1209	CAGcCCU a	caCCUUC
883	UuCGaCU C	UCCAUGC	1215	cuGGCCU U	aGCaCCG
885	CGaGUUU C	CAUGCAG	1229	GGuCCCU u	CCucAGc
905	GCGGCCU U	CuGauCG	1237	CCCAgcU C	CUGCCCC
906	CGGCCUU C	uGauCGc	1250	CCAGcCU C	CAGgCuC
919	GcGAGCU C	AGUGAGC	1268	CCCaGCU C	CuGCCCc
936	AUGGAgU U	CCAGUAC	1279	CCAUgGU c	cCuuCcu
937	UGGAgUU C	CAGUACu	1281	gUGGgcU C	AGCUgcG
942	UUCCAGU A	CuUGCCA	1286	AUGAGuU u	UccCCCA
953	GCCucAU c	CACuUGA	1309	CuCCUGU u	CgAGUCu
962	AGAuGAU C	GcCACCG	1315	cCCAGU U	CUAaCCC
965	CagUacU u	gCCaGAc	1318	CAGUcU A	aCCCCgG
973	ACCGGAU U	GAaGAGA	1331	gGGuCCU C	CcCAGuC
986	GAgACCcU u	cAAGagu	1334	CuuUuCU C	AaGCUGa
996	AGGACCcU A	UGAGACC	1389	ACGCGU C	gGAaGCC
1005	GAGACCU U	CAGAGu	1413	CUGAGU U	UGAUGcU
1006	AGACCUU C	AAGAGuA	1414	UGCAGUU U	GAUGcUG
1015	AGAGuAU C	AUGAAGA	1437	GGGGCCU U	GCUUGGC
1028	GAAGAGU C	CUUCCAa	1441	CCUUGCU U	GGCAACA
1031	GAGUCCU U	UCAauGG	1467	GgaGUGU U	CACAGAC
1032	AGUCCUU U	CAauGGA	1468	gaGUGUU C	ACAGACC
1033	GUCCUUU c	AauGGAC	1482	CUGGCAU C	uGUGGAC
1058	CCGGCCU C	CAaCCcG	1486	CuUCgGU a	GggAACT
1064	UaCACCU u	GAucCAa	1494	GACAACT C	aGAGUUU
1072	GgCGuAU U	CGUGGC	1500	UCaGAGU U	UCAGCAG
1082	UGUGCCU a	CCCGaAa	1501	CaGAGUU U	CAGCAGC
1083	aaGOCUU C	CCGaAGu	1502	aGAGUUU C	AGCAGCU
1092	CGAaACU C	AaCUUCU	1525	gGuGCAU c	CCUGUGu
1097	CUCAaCU U	CGUCCC	1566	AUGGAGU A	CCCUGAa
1098	UCAaCUU C	UGUCCCC	1577	UGAaGCU A	UAACUCC
1102	CUUCUGU C	CCCAAGC	1579	AaGCUAU A	ACTUGCC
1125	CAGCCCU A	caCCUUC	1583	UAUAACU C	GCCUGGU
1127	GCCaUAU a	gCcUUAC	1588	CUCuCCU A	GaGAggG
1131	cAUCCCU c	agCaCCA	1622	CCCAGCU C	CUGCCcC
1132	AcaCCUU c	cCagCAU	1628	UCCUGCU u	CggUaGG
1133	UCCaUcU c	CagCuUC	1648	CGGGCCU u	CCCAUUG
1137	UUUAQuU u	AgGgCgc	1660	cUGaCCU C	ugccCAG
1140	cCagCAU C	CCUcAGC	1663	cuCUgCU U	cCAGGuG
1153	GCACCAU C	AACUuUG	1664	uCUgCUU c	CAGGuGA
1158	AUCAACU u	UGAUGAG	1665	CUUgcUU u	cGGAGgU
1680	GAAGACT U	CUCCUCC			
1681	AAGACTU C	UCCUCCA			
1683	GACUUCU C	CUCCAUU			
1686	UUCUCCU C	CAUUGCG			
1690	CCUCCAU U	GCGSACA			

1704	AUGGACU U CCUGCU
1705	UGGACUU C UCUGCU
1707	GACUUCU C UGUCU
1721	uuUGAGU C AGAUCAG
1726	GUCAGAU C AGCUCCU
1731	AUCAGCU C CUAAGGU
1734	AGCUCCU A AGGUGCU
1754	CaGugCU C CCaAGAG

Table 18  
Human *rel A* HH Target Sequences  
nt. Position HH Target Sequence nt. Position HH Target Sequence

19	AAUGGCU C GUCUGUA	467	GCAGGCU A UCAGUCA
22	GGCUCGU C UGAGUG	469	AGGCUAU C AGUCAGC
26	CGUCUGU A GUGCAGG	473	UAUCAGU C AGCGCAU
93	GAACUGU U CCCCCUC	481	AGCGCAU C CAGACCA
94	AACUGUU C CCCCCA	501	AACCCCU U CCAAGUU
100	UCCCCU C AUCUUC	502	AACCCCU C CAAGUUC
103	COCUCAU C UCCCCG	508	UCCAAGU U CCUAUAG
105	CUCADCU U CCGGCA	509	CCAAGUU C CUADAGA
106	UCADCUU C CCGGAG	512	AGUUCUU A UAGAAGA
129	CAGGCUU C UGGCCCC	514	UCCCUAU A GAAGAGC
138	GGCCCUU A UGUGGAG	534	GGGGACT A CGACCUG
148	UGGAGAU C AUGAGC	556	UGCGGCU C UGCUCUC
151	AGAUCAU U GAGCAGC	561	CUUGUCU U CCAGGUG
180	AUGGCUU U CCGCUAC	562	UCUGUCU C CAGGUGA
181	UGGCUU C CGCUACA	585	GACCCAU C AGGCAGG
186	UUCGCUU A CAAGUGC	598	GGCCCUU C CGCUCGC
204	GGGCGCU C CGCGGGC	613	CGCCUGU C CUUCUCU
217	GCAGCAU C CCAGGCG	616	CUUGCCU U CCUCAUC
239	CACAGAU A CCACCA	617	UGUCCUU C CUCAUCC
262	CCAACAU C AAGAUCA	620	CCUUCUU C AUCCAUU
268	UCAAGAU C AADGGCU	623	UCCUCAU C CCAUCUU
276	AADGGCU A CACAGGA	628	ATCCCAU C UUUGACA
301	UGCGCAU C UCCUGG	630	CCCADCU U UGACAAU
303	CGCADCU C CCGGUC	631	CCAUCUU U GACAATC
310	CCUGGU C ACCAAGG	638	UGACAAU C GUGCCCC
323	GGACCCU C CUCACCG	661	CCGAGCU C AAGAUUC
326	CCUUCUU C ACGGGCC	667	UCAAGAU C UGCGGAG
335	CGGGCUU C ACCCCCA	687	CGAAACT C UGGCAGC
349	ACGAGCU U GUAGGAA	700	GCUGCCU C GGUGGGG
352	AGCUUGU A GGAAAGG	715	AUGAGAU C UUUCUAC
375	GAUGGCU U CUADGAG	717	GAGAUUU U CCUACUG
376	AUGGCUU C UADGAGG	718	AGAUCUU C CUACUGU
378	GGCUUCU A UGAGGCU	721	UCUUCUU A CUGUGUG
391	CUGAGCU C UGCCCCG	751	AGGACAU U GAGGUGU
409	GCUGCAU C CACAGUU	759	GAGGUGU A UUUCACG
416	CCACAGU U UCCAGAA	761	GGUGUAU U UCACGGG
417	CACAGUU U CCAGAAC	762	GUGUAUU U CACGGGA
418	ACAGUUU C CAGAAC	763	UGUAUUU C ACGGGAC
433	UGGSAUU C CAGUGUG	792	CGAGGCU C CUUUUCG
795	GGCUCUU U UUUGCAA	1167	GADGAGU U UCCACC
796	GCUCUUU U UGCAAG	1168	AUGAGUU U CCCACCA
797	CUCCUUU U CGCAAGC	1169	UGAGUUU C CCACCAU
798	UCCUUUU C GCAAGCU	1182	AUGGUGU U UCCUUCU
829	UGGCCAU U GUGUUC	1183	UGGUGUU U CCUCUCG
834	AUUGUGU U CCGGACC	1184	GGUGUUU C CUUCUGG

835	UUGUGUU C CGGACCC	1187	GUUUCUU U CUGGGCA
845	GACCCUU C CUAAGC	1188	UUUCCUU C UGGGCAG
849	CCUCCUU A CGCAGAC	1198	GGCAGAU C AGCCAGG
872	GCAGGCU C CUGUGCG	1209	CAGGCUU C GGCCUUG
883	UGGUGUU C UCCAUCC	1215	UCCGCCU U GGCCCGG
885	CGUGUCU C CAUGCAG	1229	GGCCCUU C CCCAAGU
905	GCGGCCU U CCGACCG	1237	CCCAAGU C CUGCCCC
906	CGGCCUU C CGACCGG	1250	CCAGGCU C CAGCCCC
919	GGGAGCU C AGUGAGC	1268	CCUGCUU C CAGCCAU
936	AUGGAUU U CCAUAAC	1279	CCAUGGU A UCAGCUC
937	UGGAUUU C CAGUACC	1281	AUGGUUU C AGCUCUG
942	UUCCAGU A CCUGCCA	1286	AUCAGCU C UGGCCCA
953	GCCAGAU A CAGAOSA	1309	CCCCUGU C CCAGUCC
962	AGACGAU C GUCAACG	1315	UCCAGU C CUAGCCC
965	CGAUCCU C ACCGGAU	1318	CAGUCCU A GCCCCAG
973	ACCGGAU U GAGGAGA	1331	AGGCCCU C CUCAGGC
986	GAAACGU A AAAGGAC	1334	CCUCCUU C AGGCUUG
996	AGSACAU A UGAGACC	1389	ACGCUGU C AGAGGCC
1005	GAGACCU U CAAGAGC	1413	CUGCAGU U UGAUGAU
1006	AGACCUU C AAGAGCA	1414	UGCAGUU U GAUGAUG
1015	AGAGCAU C ADGAAGA	1437	GGGGCCU U GCUUGGC
1028	GAAGAGU C CUUUCAG	1441	CCUUGCU U GGCAACA
1031	GAGUCCU U UCAGCGG	1467	GCGUGUU U CACAGAC
1032	AGUCCUU U CAGCGGA	1468	CUGUGUU C ACAGACC
1033	GUCCUUU C AGCGGAC	1482	CUGGCAU C CGUCCAC
1058	CGGCCCU C CACUCCG	1486	CADUCCU C GACAACU
1064	UCCACCU C GACGCAU	1494	GACAACU C CGAGUUU
1072	GACGCAU U CGUGGCG	1500	UCCGAGU U UCAGCAG
1082	UGUGCCU U CCGCAG	1501	CCGAGUU U CAGCAGC
1083	GUGCCUU C CCGCAGC	1502	CGAGUUU C AGCAGCU
1092	CGCAGCU C AGCUUCU	1525	AGGGCAU A CCUGUGG
1097	CUCAGCU U CUGUCCC	1566	AUGGAGU A CCUGAG
1098	UCAGCUU C UGUCCC	1577	UGAGGCU A UAACUCC
1102	CUUCUGU C CCCAAGC	1579	AGGCUAU A ACUCGCC
1125	CAGCCCU A UCCUUUU	1583	UAUAACU C GCCUAGU
1127	GCCCUAU C CCUUUAC	1588	CUUGCCU A GUGACAG
1131	UAUCCUU U UAUGUCA	1622	CCCAGCU C CUGCUCC
1132	AUCCUUU U ACGUCAU	1628	UCCUGCU C CACUGGG
1133	UCCUUUU A CGUCAUC	1648	CGGGGCU C CCCAUGG
1137	UUUACGU C ADCUCCG	1660	AUGGCCU C CUUUCAG
1140	ACGUCAU C CCUGAGC	1663	GCCUCCU U UCAGGAG
1153	GCACCAU C AACUAUG	1664	CCUCCUU U CAGGAGA
1158	AUCAACU A UGAUGAG	1665	CUCCUUU C AGGAGAU
1680	GAAGACTU U CUCCUCC		
1681	AAGACUU C UCCUCCA		
1683	GACUUCU C CUCCAUU		
1686	UUCUCCU C CAUUGCG		
1690	CCUCCAU U GCGGACA		
1704	ADGGACTU U CUCAGCC		

1705	UGGAGUU C	UCAGCCG
1707	GACUUCU C	AGCCCUG
1721	GCUGAGU C	AGAUCAU
1726	GUCAGAU C	AGCCCUU
1731	AUCAGCU C	CUAAGGG
1734	AGCUCCU A	AGGGGGU
1754	CUGCCCU C	CCAGAG

Table 19  
 Mouse *rel A* HH Ribozyme Sequences  
 nt. HH Ribozyme Sequence  
 Sequence

19	UCCUGUG	CUGAUGAGGCCGAAAGGCCGAA	AGCCAUU
22	CACCACG	CUGAUGAGGCCGAAAGGCCGAA	AGGAGCU
26	UGUCCGC	CUGAUGAGGCCGAAAGGCCGAA	AUGGAGG
93	GAGGGGA	CUGAUGAGGCCGAAAGGCCGAA	ACAGAUC
94	UGAGGGG	CUGAUGAGGCCGAAAGGCCGAA	AACAGAU
100	GAAAGAU	CUGAUGAGGCCGAAAGGCCGAA	AGGGGAA
103	AGGAAA	CUGAUGAGGCCGAAAGGCCGAA	AUGAGGG
105	UGAGGGA	CUGAUGAGGCCGAAAGGCCGAA	AGAUGAG
106	CUGAGGG	CUGAUGAGGCCGAAAGGCCGAA	AAGADGA
129	AGGCCCA	CUGAUGAGGCCGAAAGGCCGAA	AAGCCUG
138	CUCCACA	CUGAUGAGGCCGAAAGGCCGAA	AAGGCCC
148	GUUCGAI	CUGAUGAGGCCGAAAGGCCGAA	AUCUCCA
151	GCUGUUC	CUGAUGAGGCCGAAAGGCCGAA	AUGAUCU
180	AUAGCGG	CUGAUGAGGCCGAAAGGCCGAA	AUCGCAU
181	UAUAGCG	CUGAUGAGGCCGAAAGGCCGAA	AADCGCA
186	GCAUUUA	CUGAUGAGGCCGAAAGGCCGAA	AGCGGAA
204	GCCCCCU	CUGAUGAGGCCGAAAGGCCGAA	AGCGCCC
217	CGCCAGG	CUGAUGAGGCCGAAAGGCCGAA	AUACUGC
239	UUGGUGG	CUGAUGAGGCCGAAAGGCCGAA	AUCUGUG
262	UGAUCUU	CUGAUGAGGCCGAAAGGCCGAA	AUGGUGG
268	AGCCAUU	CUGAUGAGGCCGAAAGGCCGAA	AUCUUGA
276	UCCUGUG	CUGAUGAGGCCGAAAGGCCGAA	AGCCAUU
301	CCAGGGA	CUGAUGAGGCCGAAAGGCCGAA	AUUCGAA
303	GACCAGG	CUGAUGAGGCCGAAAGGCCGAA	AGAUUCG
310	CCUUGGU	CUGAUGAGGCCGAAAGGCCGAA	ACCAGGG
323	UCAGGAG	CUGAUGAGGCCGAAAGGCCGAA	AGGGGCC
326	GGCCGGU	CUGAUGAGGCCGAAAGGCCGAA	AGGUGGA
335	UGUGGAU	CUGAUGAGGCCGAAAGGCCGAA	AGGCCGG
349	UCCCCAC	CUGAUGAGGCCGAAAGGCCGAA	AGUCCAU
352	GCUGUUC	CUGAUGAGGCCGAAAGGCCGAA	AUGAUCU
375	CUCAUAG	CUGAUGAGGCCGAAAGGCCGAA	AGCCAUU
376	CUCCGGA	CUGAUGAGGCCGAAAGGCCGAA	AGACCAU
378	AGCCUCA	CUGAUGAGGCCGAAAGGCCGAA	AGUAGCC
391	CUGGGCA	CUGAUGAGGCCGAAAGGCCGAA	AGGUCAG
409	AGCUAUG	CUGAUGAGGCCGAAAGGCCGAA	AUACUGC
416	CUAUGGA	CUGAUGAGGCCGAAAGGCCGAA	ACUGCGG
417	GUUCUGG	CUGAUGAGGCCGAAAGGCCGAA	AGCUAUG
418	GGUUCUG	CUGAUGAGGCCGAAAGGCCGAA	AAGCUAU
433	CACACUG	CUGAUGAGGCCGAAAGGCCGAA	AUCCCCA
467	OGAACAG	CUGAUGAGGCCGAAAGGCCGAA	AGCCUGG
469	GCUGGCU	CUGAUGAGGCCGAAAGGCCGAA	AUGGCUU
473	CUGAUCU	CUGAUGAGGCCGAAAGGCCGAA	ACUCAA
481	UGGUCUG	CUGAUGAGGCCGAAAGGCCGAA	AUUCGCU

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NUC 37836

501	AACGUGA	CUGAUGAGGCGGAAAGGCGGAA	AGGGGUU
502	GAAOGUG	CUGAUGAGGCGGAAAGGCGGAA	AAGGGGU
508	CUAUAGG	CUGAUGAGGCGGAAAGGCGGAA	ACGUGAA
509	UCUADAG	CUGAUGAGGCGGAAAGGCGGAA	AACGUGA
512	UCCUCUA	CUGAUGAGGCGGAAAGGCGGAA	AGGAACG
514	GCUCUCU	CUGAUGAGGCGGAAAGGCGGAA	AUAGGAA
534	CAAGUCA	CUGAUGAGGCGGAAAGGCGGAA	AGUCCCC
556	GGAAGCA	CUGAUGAGGCGGAAAGGCGGAA	AGGCGCA
561	CACUGG	CUGAUGAGGCGGAAAGGCGGAA	AGCAGAG
562	UCACCUG	CUGAUGAGGCGGAAAGGCGGAA	AAGCAGA
585	GCUGGCU	CUGAUGAGGCGGAAAGGCGGAA	AUGGCUU
598	UCAGGAG	CUGAUGAGGCGGAAAGGCGGAA	AGGGGCC
613	GUGAGAG	CUGAUGAGGCGGAAAGGCGGAA	ACAGGGG
616	GAUGUGA	CUGAUGAGGCGGAAAGGCGGAA	AGGACAG
617	GGCGAG	CUGAUGAGGCGGAAAGGCGGAA	AAGGGAC
620	CADGGCU	CUGAUGAGGCGGAAAGGCGGAA	AGGAAGG
623	GAGAUGG	CUGAUGAGGCGGAAAGGCGGAA	AGCAGCA
628	UAUCAAA	CUGAUGAGGCGGAAAGGCGGAA	AUCGGAU
630	GUUAUCA	CUGAUGAGGCGGAAAGGCGGAA	AAAUCCG
631	GGUUAUC	CUGAUGAGGCGGAAAGGCGGAA	AAAUCCG
638	GGAAACAC	CUGAUGAGGCGGAAAGGCGGAA	AUGGCCA
661	AGAUCUU	CUGAUGAGGCGGAAAGGCGGAA	AGCUCCG
667	CUCGGCA	CUGAUGAGGCGGAAAGGCGGAA	AUCUUGA
687	GCUCUCA	CUGAUGAGGCGGAAAGGCGGAA	AGUCCCG
700	CCCCACC	CUGAUGAGGCGGAAAGGCGGAA	AGGCAGC
715	GCAAGAA	CUGAUGAGGCGGAAAGGCGGAA	AUCUCAU
717	CAGCAAG	CUGAUGAGGCGGAAAGGCGGAA	AGAUCUC
718	ACAGCAA	CUGAUGAGGCGGAAAGGCGGAA	AAGAUCU
721	CGCAADG	CUGAUGAGGCGGAAAGGCGGAA	AGGAGAA
751	ACACCUU	CUGAUGAGGCGGAAAGGCGGAA	AUGUCUU
759	CGUGAAA	CUGAUGAGGCGGAAAGGCGGAA	ACACCUU
761	CCCGUGA	CUGAUGAGGCGGAAAGGCGGAA	AUAACCC
762	UCCCGUG	CUGAUGAGGCGGAAAGGCGGAA	AAUACAC
763	GUCCCGU	CUGAUGAGGCGGAAAGGCGGAA	AAAUACA
792	AGAAAAG	CUGAUGAGGCGGAAAGGCGGAA	AGCCUCC
795	UUGAGAA	CUGAUGAGGCGGAAAGGCGGAA	AGGAGCC
796	CUUGAGA	CUGAUGAGGCGGAAAGGCGGAA	AAGGAGC
797	GCUUGAG	CUGAUGAGGCGGAAAGGCGGAA	AAAGGAG
798	AGCUUGA	CUGAUGAGGCGGAAAGGCGGAA	AAAAGGA
829	GGAAACAC	CUGAUGAGGCGGAAAGGCGGAA	AUGGCCA
834	AGUCCCG	CUGAUGAGGCGGAAAGGCGGAA	ACACAAU
835	GAGUCCG	CUGAUGAGGCGGAAAGGCGGAA	AACACAA
845	GCGUACG	CUGAUGAGGCGGAAAGGCGGAA	AGGAGUC
849	GUCGGCG	CUGAUGAGGCGGAAAGGCGGAA	ACGGAGG
872	CGAACAG	CUGAUGAGGCGGAAAGGCGGAA	AGCCUCC
883	GCADGGA	CUGAUGAGGCGGAAAGGCGGAA	ACUCGAA
885	CUGCAUG	CUGAUGAGGCGGAAAGGCGGAA	AGACUCC
905	CGAUCAG	CUGAUGAGGCGGAAAGGCGGAA	AGGCCCC
906	GCGAUCA	CUGAUGAGGCGGAAAGGCGGAA	AAGGCCG

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NUC 37837



919	GCUCACU	CUGAUGAGGCGGAAAGGCGGAA	AGCUCCG
936	GUACCGG	CUGAUGAGGCGGAAAGGCGGAA	ACUCCAU
937	AGUACUG	CUGAUGAGGCGGAAAGGCGGAA	AACUCCA
942	UGGCAAG	CUGAUGAGGCGGAAAGGCGGAA	ACUGGAA
953	UCAUGUG	CUGAUGAGGCGGAAAGGCGGAA	ADGAGGC
962	CGGUGGC	CUGAUGAGGCGGAAAGGCGGAA	ADCAUCU
965	GUCUGGC	CUGAUGAGGCGGAAAGGCGGAA	AGUACUG
973	UCUCUUC	CUGAUGAGGCGGAAAGGCGGAA	ADCCGGU
986	ACUCUUG	CUGAUGAGGCGGAAAGGCGGAA	AGGUCUC
996	GGUCUCA	CUGAUGAGGCGGAAAGGCGGAA	AGGUCCU
1005	ACUCUUG	CUGAUGAGGCGGAAAGGCGGAA	AGGUCUC
1006	UACUCUU	CUGAUGAGGCGGAAAGGCGGAA	AAGGUCU
1015	UCUUCAU	CUGAUGAGGCGGAAAGGCGGAA	AUAUCUU
1028	UUGAAAG	CUGAUGAGGCGGAAAGGCGGAA	ACUCUUC
1031	CCAUGA	CUGAUGAGGCGGAAAGGCGGAA	AGGACUC
1032	UCCAUGG	CUGAUGAGGCGGAAAGGCGGAA	AAGGACU
1033	GUCCADU	CUGAUGAGGCGGAAAGGCGGAA	AAAGGAC
1058	CGGGUUG	CUGAUGAGGCGGAAAGGCGGAA	AGGCCGG
1064	UUGGADC	CUGAUGAGGCGGAAAGGCGGAA	AGGUGUA
1072	GCACAGC	CUGAUGAGGCGGAAAGGCGGAA	AUAAGCC
1082	UUUCGGG	CUGAUGAGGCGGAAAGGCGGAA	AGGCACA
1083	ACTUCCG	CUGAUGAGGCGGAAAGGCGGAA	AAGGCUU
1092	AGAAGUU	CUGAUGAGGCGGAAAGGCGGAA	AGUUUUG
1097	GGGACAG	CUGAUGAGGCGGAAAGGCGGAA	AGUUGAG
1098	GGGGACA	CUGAUGAGGCGGAAAGGCGGAA	AAGUUGA
1102	GUUUGGG	CUGAUGAGGCGGAAAGGCGGAA	ACAGAAG
1125	GAAGGUG	CUGAUGAGGCGGAAAGGCGGAA	AGGGCUG
1127	GUAAAGC	CUGAUGAGGCGGAAAGGCGGAA	AUAAGGC
1131	UGGUGCU	CUGAUGAGGCGGAAAGGCGGAA	AGGGUUG
1132	AUGCUGG	CUGAUGAGGCGGAAAGGCGGAA	AAGGUGU
1133	GAAGCUG	CUGAUGAGGCGGAAAGGCGGAA	AGADGGA
1137	GCGGCGU	CUGAUGAGGCGGAAAGGCGGAA	AAGUAAA
1140	GCUGAGG	CUGAUGAGGCGGAAAGGCGGAA	AUGCUGG
1153	CAAAGUU	CUGAUGAGGCGGAAAGGCGGAA	AUGGUGC
1158	CUCAUCA	CUGAUGAGGCGGAAAGGCGGAA	AGUUGAU
1167	GGGGGAA	CUGAUGAGGCGGAAAGGCGGAA	ACUCADC
1168	UGGGGGA	CUGAUGAGGCGGAAAGGCGGAA	AACUCAU
1169	AUGGGGG	CUGAUGAGGCGGAAAGGCGGAA	AAACUCA
1182	UGADGGU	CUGAUGAGGCGGAAAGGCGGAA	ACAGCAU
1183	CUGAUGG	CUGAUGAGGCGGAAAGGCGGAA	AACAGCA
1184	UCAGGAG	CUGAUGAGGCGGAAAGGCGGAA	AGGGGCC
1187	GGCUGAG	CUGAUGAGGCGGAAAGGCGGAA	AAGGGAC
1188	CUGCCCU	CUGAUGAGGCGGAAAGGCGGAA	AUGGUAA
1198	UCAGACT	CUGAUGAGGCGGAAAGGCGGAA	AACUCCC
1209	GAAGGUG	CUGAUGAGGCGGAAAGGCGGAA	AGGGCUG
1215	CGGUGCU	CUGAUGAGGCGGAAAGGCGGAA	AGGCCAG
1229	GCUGAGG	CUGAUGAGGCGGAAAGGCGGAA	AGGGACC
1237	GGGGCAG	CUGAUGAGGCGGAAAGGCGGAA	AGCUGGG
1250	GAGCCUG	CUGAUGAGGCGGAAAGGCGGAA	AGGCUGG

1268	GGGGCAG	CUGADGAGGCCGAAAGGCCGAA	AGCUGGG
1279	AGGAAGG	CUGADGAGGCCGAAAGGCCGAA	ACCAUGG
1281	CGCAGCU	CUGADGAGGCCGAAAGGCCGAA	AGCCAC
1286	UGGGGGA	CUGADGAGGCCGAAAGGCCGAA	AACUCAU
1309	AGACUCG	CUGADGAGGCCGAAAGGCCGAA	ACAGGAG
1315	GGGUUAG	CUGADGAGGCCGAAAGGCCGAA	ACUGGGG
1318	CGGGGUU	CUGADGAGGCCGAAAGGCCGAA	AGAACUG
1331	GACUGGG	CUGADGAGGCCGAAAGGCCGAA	AGGACCC
1334	UCAGCUU	CUGADGAGGCCGAAAGGCCGAA	AGAAAAG
1389	GGCUUCC	CUGADGAGGCCGAAAGGCCGAA	ACAGCGU
1413	AGCAUCA	CUGADGAGGCCGAAAGGCCGAA	ACUGCAG
1414	CAGCAUC	CUGADGAGGCCGAAAGGCCGAA	AACUGCA
1437	GCCAAGC	CUGADGAGGCCGAAAGGCCGAA	AGGCCCC
1441	UGUUGCC	CUGADGAGGCCGAAAGGCCGAA	AGCAAGG
1467	GUUGUG	CUGADGAGGCCGAAAGGCCGAA	ACACUCC
1468	GGUCUGU	CUGADGAGGCCGAAAGGCCGAA	AACACUC
1482	GUCCACA	CUGADGAGGCCGAAAGGCCGAA	ADGCCAG
1486	AGUUCOC	CUGADGAGGCCGAAAGGCCGAA	ACCGAAG
1494	AAACUCU	CUGADGAGGCCGAAAGGCCGAA	AGUUGUC
1500	CUGCUGA	CUGADGAGGCCGAAAGGCCGAA	ACUCUGA
1501	GUCUGUG	CUGADGAGGCCGAAAGGCCGAA	AACUCUG
1502	AGCUGCU	CUGADGAGGCCGAAAGGCCGAA	AAACUCU
1525	ACACAGG	CUGADGAGGCCGAAAGGCCGAA	ADGCACC
1566	UUCAGGG	CUGADGAGGCCGAAAGGCCGAA	ACUCCAU
1577	CGAGUUA	CUGADGAGGCCGAAAGGCCGAA	AGCUUCA
1579	GGCGAGU	CUGADGAGGCCGAAAGGCCGAA	ADAGCTU
1583	ACCAGGC	CUGADGAGGCCGAAAGGCCGAA	AGUUADA
1588	CCUCUC	CUGADGAGGCCGAAAGGCCGAA	AGGAGAG
1622	GGGGCAG	CUGADGAGGCCGAAAGGCCGAA	AGCUGGG
1628	CCUACCG	CUGADGAGGCCGAAAGGCCGAA	AGCAGGA
1648	CAUUGGG	CUGADGAGGCCGAAAGGCCGAA	AGCCOOG
1660	CUGGGCA	CUGADGAGGCCGAAAGGCCGAA	AGGUCAG
1663	CACUUGG	CUGADGAGGCCGAAAGGCCGAA	AGCAGAG
1664	UCACCUG	CUGADGAGGCCGAAAGGCCGAA	AAGCAGA
1665	ACCUCCG	CUGADGAGGCCGAAAGGCCGAA	AAGCGAG
1680	GGAGGAG	CUGADGAGGCCGAAAGGCCGAA	AGUCUUC
1681	UGGAGGA	CUGADGAGGCCGAAAGGCCGAA	AAGUCUU
1683	AADGGAG	CUGADGAGGCCGAAAGGCCGAA	AGAAGUC
1686	CGCAUDG	CUGADGAGGCCGAAAGGCCGAA	AGGAGAA
1690	UGUCGCG	CUGADGAGGCCGAAAGGCCGAA	ADGGAGG
1704	AGCAGAG	CUGADGAGGCCGAAAGGCCGAA	AGUCCAU
1705	GAGCAGA	CUGADGAGGCCGAAAGGCCGAA	AAGUCCA
1707	AAGAGCA	CUGADGAGGCCGAAAGGCCGAA	AGAAGUC
1721	CUGAUCU	CUGADGAGGCCGAAAGGCCGAA	ACUCAAA
1726	AGGAGCU	CUGADGAGGCCGAAAGGCCGAA	AUCUGAC
1731	ACCUUAG	CUGADGAGGCCGAAAGGCCGAA	AGCUGAU
1734	AGCACCU	CUGADGAGGCCGAAAGGCCGAA	AGGAGCU
1754	CUCUUGG	CUGADGAGGCCGAAAGGCCGAA	AGCACUG

Table 20  
Human *rel A* HH Ribozyme Sequences  
nt. Position HH Ribozyme Sequences

19	UACAGAC	CUGADGAGGCCGAAAGGCCGAA	AGCCAUU
22	CACUACA	CUGADGAGGCCGAAAGGCCGAA	ACGAGCC
26	CGUGCAC	CUGADGAGGCCGAAAGGCCGAA	ACAGACG
93	GAGGGGG	CUGADGAGGCCGAAAGGCCGAA	ACAGUUC
94	UGAGGGG	CUGADGAGGCCGAAAGGCCGAA	AACAGUU
100	GGAAGAU	CUGADGAGGCCGAAAGGCCGAA	AGGGGGA
103	CCGGGAA	CUGADGAGGCCGAAAGGCCGAA	AUGAGGG
105	UGCCGGG	CUGADGAGGCCGAAAGGCCGAA	AGAUGAG
106	CUGCCGG	CUGADGAGGCCGAAAGGCCGAA	AAGAUGA
129	GGGGCCA	CUGADGAGGCCGAAAGGCCGAA	AGGCCUG
138	CUCCACA	CUGADGAGGCCGAAAGGCCGAA	AGGGGCC
148	GUCAAUU	CUGADGAGGCCGAAAGGCCGAA	AUCUCCA
151	GUUCUUC	CUGADGAGGCCGAAAGGCCGAA	AUGAUUU
180	GUAGCGG	CUGADGAGGCCGAAAGGCCGAA	AGCGCAU
181	UGUAGCG	CUGADGAGGCCGAAAGGCCGAA	AAGCGCA
186	GCACUUG	CUGADGAGGCCGAAAGGCCGAA	AGCGGAA
204	GCCCCCG	CUGADGAGGCCGAAAGGCCGAA	AGCGCCC
217	CGCCUGG	CUGADGAGGCCGAAAGGCCGAA	AUGCUUG
239	UUGGUGG	CUGADGAGGCCGAAAGGCCGAA	AUCUGUG
262	UGAUCUU	CUGADGAGGCCGAAAGGCCGAA	AUGGUGG
268	AGCCAUU	CUGADGAGGCCGAAAGGCCGAA	AUCUUGA
276	UCCUGUG	CUGADGAGGCCGAAAGGCCGAA	AGCCAUU
301	CCAGGGA	CUGADGAGGCCGAAAGGCCGAA	AUGCGCA
303	GACCAGG	CUGADGAGGCCGAAAGGCCGAA	AGAUGCG
310	CCUUGGU	CUGADGAGGCCGAAAGGCCGAA	ACCAGGG
323	CGGUGAG	CUGADGAGGCCGAAAGGCCGAA	AGGGUCC
326	GGCCGGU	CUGADGAGGCCGAAAGGCCGAA	AGGAGGG
335	UGGGGGU	CUGADGAGGCCGAAAGGCCGAA	AGGCCGG
349	UUCCUAC	CUGADGAGGCCGAAAGGCCGAA	AGCUCGU
352	CCUUUCC	CUGADGAGGCCGAAAGGCCGAA	ACAAGCU
375	CUCAUAG	CUGADGAGGCCGAAAGGCCGAA	AGCCAUU
376	CCUCAUA	CUGADGAGGCCGAAAGGCCGAA	AAGCCAU
378	AGCCUCA	CUGADGAGGCCGAAAGGCCGAA	AGAAGCC
391	CCGGGCA	CUGADGAGGCCGAAAGGCCGAA	AGCUCAG
409	AACUGUG	CUGADGAGGCCGAAAGGCCGAA	AUGCAGC
416	UUCUGGA	CUGADGAGGCCGAAAGGCCGAA	ACUGUGG
417	GUUCUGG	CUGADGAGGCCGAAAGGCCGAA	AACUGUG
418	GGUUCUG	CUGADGAGGCCGAAAGGCCGAA	AAACUGU
433	CACACUG	CUGADGAGGCCGAAAGGCCGAA	AUUCCCA
467	UGACUGA	CUGADGAGGCCGAAAGGCCGAA	AGCCUGC
469	GCTUGACU	CUGADGAGGCCGAAAGGCCGAA	AUAGCCU
473	AUGCGCU	CUGADGAGGCCGAAAGGCCGAA	ACUGAUA
481	UGGUCUG	CUGADGAGGCCGAAAGGCCGAA	AUGCGCU
501	AACUUGG	CUGADGAGGCCGAAAGGCCGAA	AGGGGUU

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502	GAACUUG	CUGADGAGGCGGAAAGGCGGAA	AAGGGGU
508	CUADAGG	CUGADGAGGCGGAAAGGCGGAA	ACUUGGA
509	UCUAUAG	CUGADGAGGCGGAAAGGCGGAA	AACDUGG
512	UCUUCUA	CUGADGAGGCGGAAAGGCGGAA	AGGAACU
514	GCUCUUC	CUGADGAGGCGGAAAGGCGGAA	ADAGGAA
534	CAGGUCC	CUGADGAGGCGGAAAGGCGGAA	AGUCCCC
556	GGAAGCA	CUGADGAGGCGGAAAGGCGGAA	AGCCGCA
561	CACCUCC	CUGADGAGGCGGAAAGGCGGAA	AGCAGAG
562	UCACTUG	CUGADGAGGCGGAAAGGCGGAA	AAGCAGA
585	CCUGCCU	CUGADGAGGCGGAAAGGCGGAA	ADGGGUC
598	GCAGSCG	CUGADGAGGCGGAAAGGCGGAA	AGGGGCC
613	GAGGAAG	CUGADGAGGCGGAAAGGCGGAA	ACAGGCG
616	GAUGAGG	CUGADGAGGCGGAAAGGCGGAA	AGGACAG
617	GGADGAG	CUGADGAGGCGGAAAGGCGGAA	AAGGACA
620	AUGGGAU	CUGADGAGGCGGAAAGGCGGAA	AGGAAGG
623	AAGAUGG	CUGADGAGGCGGAAAGGCGGAA	ADGAGGA
628	UGUCAA	CUGADGAGGCGGAAAGGCGGAA	AUGGGAU
630	AUUGUCA	CUGADGAGGCGGAAAGGCGGAA	AGADGGG
631	GAUUGUC	CUGADGAGGCGGAAAGGCGGAA	AAGAUGG
638	GGGGCAC	CUGADGAGGCGGAAAGGCGGAA	AUUGUCA
661	AGAUCUU	CUGADGAGGCGGAAAGGCGGAA	AGCUCCG
667	CUCCGCA	CUGADGAGGCGGAAAGGCGGAA	ADCUUGA
687	GCUGCCA	CUGADGAGGCGGAAAGGCGGAA	AGUUUCG
700	CCCCACC	CUGADGAGGCGGAAAGGCGGAA	AGGCAGC
715	GUAGGAA	CUGADGAGGCGGAAAGGCGGAA	ADUCUAU
717	CAGUAGG	CUGADGAGGCGGAAAGGCGGAA	AGAUUCU
718	ACAGUAG	CUGADGAGGCGGAAAGGCGGAA	AAGADCU
721	CACACAG	CUGADGAGGCGGAAAGGCGGAA	AGGAAGA
751	ACACUUC	CUGADGAGGCGGAAAGGCGGAA	ADGUCCU
759	CGUGAAA	CUGADGAGGCGGAAAGGCGGAA	ACACUUC
761	CCCGUGA	CUGADGAGGCGGAAAGGCGGAA	AUACACC
762	UCCCGUG	CUGADGAGGCGGAAAGGCGGAA	AAUACAC
763	GUCCCGU	CUGADGAGGCGGAAAGGCGGAA	AAAUACA
792	CGAAAAG	CUGADGAGGCGGAAAGGCGGAA	AGCCUCC
795	UUUGGAA	CUGADGAGGCGGAAAGGCGGAA	AGGAGCC
796	CUUGCGA	CUGADGAGGCGGAAAGGCGGAA	AAGGAGC
797	GCUUGCG	CUGADGAGGCGGAAAGGCGGAA	AAAGGAG
798	AGCUUGC	CUGADGAGGCGGAAAGGCGGAA	AAAAGGA
829	GGAACAC	CUGADGAGGCGGAAAGGCGGAA	AUGGCCA
834	GGUCCGG	CUGADGAGGCGGAAAGGCGGAA	ACACAAU
835	GGGUCCG	CUGADGAGGCGGAAAGGCGGAA	AACACAA
845	GCGUAGG	CUGADGAGGCGGAAAGGCGGAA	AGGGGUC
849	GUCUGCG	CUGADGAGGCGGAAAGGCGGAA	AGGGAGG
872	CGCACAG	CUGADGAGGCGGAAAGGCGGAA	AGCCUCC
883	GCAUGGA	CUGADGAGGCGGAAAGGCGGAA	ACACGCA
885	CUGCAUG	CUGADGAGGCGGAAAGGCGGAA	AGACACG
905	CGGUCCG	CUGADGAGGCGGAAAGGCGGAA	AGGCCGC
906	CCGGUCC	CUGADGAGGCGGAAAGGCGGAA	AAGGCCG
919	GCUCACU	CUGADGAGGCGGAAAGGCGGAA	AGCUCCC

936	GUACUGG	CUGAUGAGGCCGAAAGGCCGAA	AUUCCAU
937	GGUACUG	CUGAUGAGGCCGAAAGGCCGAA	AAUUGCA
942	UGGCAGG	CUGAUGAGGCCGAAAGGCCGAA	ACUGGAA
953	UCGUCUG	CUGAUGAGGCCGAAAGGCCGAA	AUCUGGC
962	CGGUGAC	CUGAUGAGGCCGAAAGGCCGAA	AUCGUCU
965	AUCCGGU	CUGAUGAGGCCGAAAGGCCGAA	ACGAUCG
973	UCUCCUC	CUGAUGAGGCCGAAAGGCCGAA	AUCCGGU
986	GUCUUUU	CUGAUGAGGCCGAAAGGCCGAA	ACGUUUC
996	GGUCUCA	CUGAUGAGGCCGAAAGGCCGAA	AUGUCCU
1005	GCUCUUG	CUGAUGAGGCCGAAAGGCCGAA	AGGUUUC
1006	UGCUCUU	CUGAUGAGGCCGAAAGGCCGAA	AAGGUUC
1015	UCUUCAU	CUGAUGAGGCCGAAAGGCCGAA	AUGCUCU
1028	CUGAAAG	CUGAUGAGGCCGAAAGGCCGAA	ACUCUUC
1031	CCGUCUA	CUGAUGAGGCCGAAAGGCCGAA	AGGACUC
1032	UCCGUCG	CUGAUGAGGCCGAAAGGCCGAA	AAGGACU
1033	GUCGUCU	CUGAUGAGGCCGAAAGGCCGAA	AAAGGAC
1058	CGAGGUG	CUGAUGAGGCCGAAAGGCCGAA	AGGCGCG
1064	AUGCGUC	CUGAUGAGGCCGAAAGGCCGAA	AGGUGGA
1072	GCACAGC	CUGAUGAGGCCGAAAGGCCGAA	AUGCGUC
1082	CUGCGGG	CUGAUGAGGCCGAAAGGCCGAA	AGGCACA
1083	GCUGCGG	CUGAUGAGGCCGAAAGGCCGAA	AAGGCAC
1092	AGAAGCU	CUGAUGAGGCCGAAAGGCCGAA	AGCUGCG
1097	GGGACAG	CUGAUGAGGCCGAAAGGCCGAA	AGCUGAG
1098	GGGGAUA	CUGAUGAGGCCGAAAGGCCGAA	AAGCUGA
1102	GCUUGGG	CUGAUGAGGCCGAAAGGCCGAA	ACAGAAG
1125	AAAGGGA	CUGAUGAGGCCGAAAGGCCGAA	AGGGCUG
1127	GUAAAGG	CUGAUGAGGCCGAAAGGCCGAA	AUAGGGC
1131	UGACGUA	CUGAUGAGGCCGAAAGGCCGAA	AGGGGUA
1132	AUGACGU	CUGAUGAGGCCGAAAGGCCGAA	AAGGGAU
1133	GAUGACG	CUGAUGAGGCCGAAAGGCCGAA	AAAGGGA
1137	CAGGGAU	CUGAUGAGGCCGAAAGGCCGAA	ACGUAAA
1140	GCUCAGG	CUGAUGAGGCCGAAAGGCCGAA	AUGACGU
1153	CAUAGUU	CUGAUGAGGCCGAAAGGCCGAA	AUGGUGC
1158	CUCADCA	CUGAUGAGGCCGAAAGGCCGAA	AGUUGAU
1167	GGUGGGA	CUGAUGAGGCCGAAAGGCCGAA	ACUCAUC
1168	UGGUGGG	CUGAUGAGGCCGAAAGGCCGAA	AACUCAU
1169	AUGGUGG	CUGAUGAGGCCGAAAGGCCGAA	AAACUCA
1182	AGAAGGA	CUGAUGAGGCCGAAAGGCCGAA	ACACCAU
1183	CAGAAAG	CUGAUGAGGCCGAAAGGCCGAA	AACACCA
1184	CCAGAAG	CUGAUGAGGCCGAAAGGCCGAA	AAACACC
1187	UGCCAG	CUGAUGAGGCCGAAAGGCCGAA	AGGAAAC
1188	CUGCCCA	CUGAUGAGGCCGAAAGGCCGAA	AAGGAAA
1198	CCUGGCU	CUGAUGAGGCCGAAAGGCCGAA	AUCUGCC
1209	CAAGGCC	CUGAUGAGGCCGAAAGGCCGAA	AGGCCUG
1215	CGGGGCC	CUGAUGAGGCCGAAAGGCCGAA	AGGCCGA
1229	ACUUGGG	CUGAUGAGGCCGAAAGGCCGAA	AGGGGCC
1237	GGGGCAG	CUGAUGAGGCCGAAAGGCCGAA	ACUUGGG
1250	GGGGCUG	CUGAUGAGGCCGAAAGGCCGAA	AGCCUGG
1268	AUGGCUG	CUGAUGAGGCCGAAAGGCCGAA	AGCAGGG

1279	GAGCUGA	CUGAUGAGGCGGAAAGGCCGAA	ACCAUGG
1281	CAGAGCU	CUGAUGAGGCGGAAAGGCCGAA	AUACCAU
1286	UGGGCCA	CUGAUGAGGCGGAAAGGCCGAA	AGCUGAU
1309	GGACUGG	CUGAUGAGGCGGAAAGGCCGAA	ACAGGGG
1315	GGGCUAG	CUGAUGAGGCGGAAAGGCCGAA	ACUGGGA
1318	CUGGGGC	CUGAUGAGGCGGAAAGGCCGAA	AGGACUG
1331	GCCUGAG	CUGAUGAGGCGGAAAGGCCGAA	AGGGCCU
1334	ACAGCCU	CUGAUGAGGCGGAAAGGCCGAA	AGGAGGG
1389	GGCCUCU	CUGAUGAGGCGGAAAGGCCGAA	ACAGCGU
1413	AUCAUCA	CUGAUGAGGCGGAAAGGCCGAA	ACUGCAG
1414	CAUCAUC	CUGAUGAGGCGGAAAGGCCGAA	AACUGCA
1437	GCCAAAC	CUGAUGAGGCGGAAAGGCCGAA	AGGCCCC
1441	UGUUGCC	CUGAUGAGGCGGAAAGGCCGAA	AGCAAGG
1467	GUCUGUG	CUGAUGAGGCGGAAAGGCCGAA	ACACAGC
1468	GGUCUGU	CUGAUGAGGCGGAAAGGCCGAA	AACACAG
1482	GUUGACG	CUGAUGAGGCGGAAAGGCCGAA	AUGOCAG
1486	AGUUGUC	CUGAUGAGGCGGAAAGGCCGAA	ACGGAUG
1494	AAACUUG	CUGAUGAGGCGGAAAGGCCGAA	AGUUGUC
1500	CUGCUGA	CUGAUGAGGCGGAAAGGCCGAA	ACUUGGA
1501	GCUGCUG	CUGAUGAGGCGGAAAGGCCGAA	AACUUGG
1502	AGCUGCU	CUGAUGAGGCGGAAAGGCCGAA	AAACUUG
1525	CCACAGG	CUGAUGAGGCGGAAAGGCCGAA	AUGCCCU
1566	CUCAGGG	CUGAUGAGGCGGAAAGGCCGAA	ACUCCAU
1577	CGAGUUA	CUGAUGAGGCGGAAAGGCCGAA	AGCCUCA
1579	GGGAGU	CUGAUGAGGCGGAAAGGCCGAA	AUAGCCU
1583	ACUAGGC	CUGAUGAGGCGGAAAGGCCGAA	AGUUAUA
1588	CUGUCAC	CUGAUGAGGCGGAAAGGCCGAA	AGGCGAG
1622	GGAGCAG	CUGAUGAGGCGGAAAGGCCGAA	AGCUGGG
1628	CCAGUG	CUGAUGAGGCGGAAAGGCCGAA	AGCAGGA
1648	CAUUGGG	CUGAUGAGGCGGAAAGGCCGAA	AGCCCCG
1660	CUGAAAG	CUGAUGAGGCGGAAAGGCCGAA	AGGCCAU
1663	CUCCUGA	CUGAUGAGGCGGAAAGGCCGAA	AGGAGGC
1664	UCUCCUG	CUGAUGAGGCGGAAAGGCCGAA	AAGGAGG
1665	AUCUCCU	CUGAUGAGGCGGAAAGGCCGAA	AAAGGAG
1680	GGAGGAG	CUGAUGAGGCGGAAAGGCCGAA	AGUCUUC
1681	UGGAGGA	CUGAUGAGGCGGAAAGGCCGAA	AAGOCUU
1683	AAUGGAG	CUGAUGAGGCGGAAAGGCCGAA	AGAAGUC
1686	CGCAUUG	CUGAUGAGGCGGAAAGGCCGAA	AGGAGAA
1690	UGUCCGC	CUGAUGAGGCGGAAAGGCCGAA	AUGGAGG
1704	GGCUGAG	CUGAUGAGGCGGAAAGGCCGAA	AGUCCAU
1705	GGGCUGA	CUGAUGAGGCGGAAAGGCCGAA	AAGUCCA
1707	CAGGGCU	CUGAUGAGGCGGAAAGGCCGAA	AGAAGUC
1721	CUGAUCU	CUGAUGAGGCGGAAAGGCCGAA	ACUCAGC
1726	AGGAGCU	CUGAUGAGGCGGAAAGGCCGAA	AUCUGAC
1731	CCCUUAG	CUGAUGAGGCGGAAAGGCCGAA	AGCUGAU
1734	ACCCCCU	CUGAUGAGGCGGAAAGGCCGAA	AGGAGCU
1754	CUCUGGG	CUGAUGAGGCGGAAAGGCCGAA	AGGCCAG

Table 21  
Human *rel/A* Halprin Ribozyme/Target Sequences  
nt. Position Halprin Ribozyme sequence

Position	Halpin Ribozyme sequence				Substrate			
90	UGAGGGGG	AGAA	GUUC	ACCAGAGAAACACACGUGUGUGGUACAUAUACCUGGUA	GAACU	GUU	CCCCCUCA	
156	GCUGCUUG	AGAA	GCUC	ACCAGAGAAACACACGUGUGUGGUACAUAUACCUGGUA	GAGCA	GCC	CNAGCAGC	
362	GCCAUCCC	AGAA	GUCC	ACCAGAGAAACACACGUGUGUGGUACAUAUACCUGGUA	GGACU	GCC	GGGAUGGC	
413	GUUCUGGA	AGAA	GUGG	ACCAGAGAAACACACGUGUGUGGUACAUAUACCUGGUA	CCACA	GUU	UCCAGAAC	
606	GAAGGACA	AGAA	GCAG	ACCAGAGAAACACACGUGUGUGGUACAUAUACCUGGUA	CUGCC	GCC	UGUCCUUC	
652	UUGAGCUC	AGAA	GUGU	ACCAGAGAAACACACGUGUGUGGUACAUAUACCUGGUA	ACACU	GCC	GAGCUCAA	
695	CCCACCGA	AGAA	GCUG	ACCAGAGAAACACACGUGUGUGGUACAUAUACCUGGUA	CAGCU	GCC	UCCGUUGG	
853	AGGCUGGG	AGAA	GGCU	ACCAGAGAAACACACGUGUGUGGUACAUAUACCUGGUA	ACCCA	GAC	CCCAGCCU	
900	GGUCGGAA	AGAA	GGCG	ACCAGAGAAACACACGUGUGUGGUACAUAUACCUGGUA	CGGCG	GCC	UUCCGACC	
955	UGACCAUC	AGAA	GUAU	ACCAGAGAAACACACGUGUGUGGUACAUAUACCUGGUA	AUACA	GAC	GAUCGUCA	
1037	GUCGGUGG	AGAA	GCUG	ACCAGAGAAACACACGUGUGUGGUACAUAUACCUGGUA	CAGCG	GAC	CCACCAGC	
1045	GGCCGGGG	AGAA	GUGG	ACCAGAGAAACACACGUGUGUGGUACAUAUACCUGGUA	CCACC	GAC	CCCCGGCC	
1410	CAUCAUCA	AGAA	GCAG	ACCAGAGAAACACACGUGUGUGGUACAUAUACCUGGUA	CUCCA	GUU	UGAUGAUG	
1453	ACAGCUGG	AGAA	GUGC	ACCAGAGAAACACACGUGUGUGGUACAUAUACCUGGUA	GCACA	GAC	CCAGCUGU	
1471	GAUGCCAG	AGAA	GUGA	ACCAGAGAAACACACGUGUGUGGUACAUAUACCUGGUA	UCACA	GAC	CUGGCNAUC	

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Table 22  
Mouse *rel/A* Hairpin Ribozyme/Target Sequences  
nt. Position Hairpin Ribozyme sequence

		Substrate
137	GUUGCUUC AGAA GUUC ACCAGAGAAAACACACGUGUGUGUACAUAUACCUUGGUA	GAACA GGC GAAGCAAC
273	GAGAUUCG AGAA GUUC ACCAGAGAAAACACACGUGUGUGUACAUAUACCUUGGUA	GAACA GUU CGAAUUC
343	GCCAUCCG AGAA GUCC ACCAGAGAAAACACACGUGUGUGUACAUAUACCUUGGUA	GAACU GGC GCGAUUGC
366	GCGCAGAG AGAA GCGU ACCAGAGAAAACACACGUGUGUGUACAUAUACCUUGGUA	AGGCU GAC CUCUGGCC
633	UUGAGCTUC AGAA GUGU ACCAGAGAAAACACACGUGUGUGUACAUAUACCUUGGUA	ACACU GGC GAGTUCNA
676	CCACCCGA AGAA GCUC ACCAGAGAAAACACACGUGUGUGUACAUAUACCUUGGUA	GAGCU GGC UCGGUGGG
834	AGGCTGGG AGAA GCGU ACCAGAGAAAACACACGUGUGUGUACAUAUACCUUGGUA	ACGCC GAC CCCAGGCU
881	GAUCAGAA AGAA GCGG ACCAGAGAAAACACACGUGUGUGUACAUAUACCUUGGUA	CGCGG GGC UUCUGAUC
1100	AGGUGUAG AGAA GCGG ACCAGAGAAAACACACGUGUGUGUACAUAUACCUUGGUA	CCGCA GGC CUAACAUCU
1205	GGGCAGAG AGAA GUGC ACCAGAGAAAACACACGUGUGUGUACAUAUACCUUGGUA	GCACC GUC CUCUGGCC
1361	GCGCTUCC AGAA GCGU ACCAGAGAAAACACACGUGUGUGUACAUAUACCUUGGUA	ACGCU GUC CGAAAGGCC
1385	CAGCAUCA AGAA GCAG ACCAGAGAAAACACACGUGUGUGUACAUAUACCUUGGUA	CUGCA GUU UGAUGCUG
1431	ACUCCUGG AGAA GUGC ACCAGAGAAAACACACGUGUGUGUACAUAUACCUUGGUA	GCACA GAC GCAGGAGU
1449	GAUGCCAG AGAA GUGA ACCAGAGAAAACACACGUGUGUGUACAUAUACCUUGGUA	UCACA GAC CUGGCAUC
1802	AAGUCGGG AGAA GCUU ACCAGAGAAAACACACGUGUGUGUACAUAUACCUUGGUA	CAGCU GGC CCCGACTU
2009	UGGCUCCA AGAA GCUU ACCAGAGAAAACACACGUGUGUGUACAUAUACCUUGGUA	GGACA GAC UGGAGGCA
2124	UGGUGUCG AGAA GCAC ACCAGAGAAAACACACGUGUGUGUACAUAUACCUUGGUA	GUGCU GGC CGACACCA
2233	AUUCUGAA AGAA GCCA ACCAGAGAAAACACACGUGUGUGUACAUAUACCUUGGUA	UGGCC GGC UUCAGAAU
2354	UCAGUAAA AGAA GUCU ACCAGAGAAAACACACGUGUGUGUACAUAUACCUUGGUA	AGACA GGC UUUACUGA

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Table 23: Human TNF- $\alpha$  HH Ribozyme Target Sequence

nt. Position	HH Target Sequence	nt. Position	HH Target Sequence
28	GGCAGGU U CUCUUC	321	GUCAGAU C AUCUUCU
29	GCAGGUU C UCUUCCU	324	AGAUCAU C UUCUGGA
31	AGGUUCU C UUCUUCU	326	AUCAUU C CUCGAAC
33	GUUCUCU U CCUCUCA	327	UCAUCU C UCGAACC
34	UUCUCU C CUCUCAC	329	AUCUUCU C GAACCCC
37	UCUUCU C UCACUA	352	AGCCUGU A GOCUUG
39	UUCUCU C ACAUACU	361	CCCAUGU U GUAGCAA
44	CUCACAU A CUGACCC	364	AUGUUGU A GCAAACC
58	CACGGCU C CACCCUC	374	AAACCCU C AAGCUGA
65	CCACCCU C UCUCCCC	391	GGCAGCU C CAGUGGC
67	ACCCUCU C UCCUCUG	421	AUGCCCU C CUGGCCA
69	CCUCUCU C CUCUGGA	449	GAGAGAU A ACCAGCU
106	GCAUGAU C CGGGACG	468	GUGCCAU C AGAGGGC
136	AGGCGCU C CCAAGA	480	GGCCUGU A CCUCAUC
165	CAGGGCU C CAGGCGG	484	UGUACCU C AUCUACU
177	CGGUGCU U GUUCUUC	487	ACCUCAU C UACUCCC
180	UGCUGU U CCUCAGC	489	CUCAUCU A CUCCAG
181	GCUGGU C CUCAGCC	492	AUCUACU C CAGGUC
184	UGUUCU C AGCUCU	499	CCCAGGU C CUCUCA
190	UCAGCU C UUCUUCU	502	AGGUCCU C UUCAAGG
192	AGCCUCU U CUCCUUC	504	GUCCUCU U CAAGGGC
193	GCCUCU C UCCUUC	505	UCCUCU C AAGGGCC
195	CUCUCU C CUUCCUG	525	UGCCCU C CACCCAU
198	UUCUCU U CCUGAUC	538	AUGUGCU C CUCACCC
199	UCUCU C CUGAUCG	541	UCUCCU C ACCACA
205	UCCUGAU C GUGGCAG	553	ACACCAU C AGCGCA
226	CCAGCU C UUCUGCC	562	GCGCAU C GCGUCU
228	ACGCUU U CUGCCUG	568	UCGCGU C UCCUACC
229	CGCUCU C UGCGUG	570	GCGUCU C CUAACAG
243	CUGCAU U UGGAGUG	573	GUCCCU A CCAGACC
244	UGCACU U GGAGUGA	586	CCAAGGU C AACCUCC
253	GAGUGAU C GGGCCCC	592	UCAACU C CUCUCUG
273	GAAGAU C CCCCAGG	595	ACCUCU C UCGCCA
286	GGGACU C UCUCUAA	597	CUCCUCU C UGCAUC
288	GACCU C UCUAUUC	604	CUGCCAU C AAGAGCC
290	CCUCUCU C UAADCAG	657	CCUGGU A UGAGCCC
292	UCUCUCU A AUCAGCC	667	AGCCAU C UAUCUGG
295	CUCUAU C AGCCUC	669	CCCAUCU A UCUGGGA
302	CAGCCU C UGGGCCA		

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671	CAUCUUAU C UGGGAGG	960	UGGGAUU C AGGAUUG
682	GAGGGGU C UUCCAGC	1001	AACCACU A AGAAUUC
684	GGGGUCU U CCAGCUG	1007	UAAGAAU U CAAACUG
685	GGGUUCU C CAGCUGG	1008	AAGAAUU C AAACUGG
709	ACCGACU C AGGCUG	1021	GGGGCCU C CAGAACU
721	CUGAGAU C AAUCGGC	1029	CAGAACU C ACUGGGG
725	GADCAAU C GGCCCGA	1040	GGGGCCU A CAGCUUU
735	CCCGACU A UCUCGAC	1046	UACAGCU U UGADCCG
737	CGACUUAU C UCGACUU	1047	ACAGCUU U GAUCCCU
739	ACUACU C GACUUUG	1051	CUUUGAU C CCUGACA
744	CUCGACU U UGCGGAG	1060	CUGACAU C UGGAUUC
745	UGGACUU U GCGGAGU	1067	CUGGAUU C UGGAGAC
753	GCCGAGU C UGGGCAG	1085	GGAGCCU U UGGUUCU
763	GGCAGGU C UACUUUG	1086	GAGCCUU U GGUUCUG
765	CAGGUUU A CUUUGGG	1090	CUUUGGU U CUGGCCA
768	GUUACU U UGGGADC	1091	UUUGGUU C UGGCCAG
769	UCUACUU U GGGAUCA	1113	CAGGACU U GAGAAGA
775	UUGGGAU C AUUGCCC	1124	AAGACCU C ACCUAGA
778	GGAUCAU U GCGCGU	1129	CUACCUU A GAAAUUG
801	CGAACAU C CAACUUU	1135	UAGAAAU U GACACAA
808	CCAACCU U CCAAAAC	1151	UGGACCU U AGGCCUU
809	CAACCUU C CCAAAAG	1152	GGACCUU A GGCUCUC
820	AAAGCCU C CCGGCGC	1158	UAGGCCU U CCUCUCU
833	CCCGAAU C CCUUUAU	1159	AGGCCU C CCUCUCU
837	AADCCCU U UAUAUAC	1162	CCUUCU C UCCCCAG
838	AUCCCUU U AUUAACC	1164	UUCCUCU C UCCAGAU
839	UCCCUUU A UUAACCC	1166	CCUUCU C CAGAUUU
841	CCUUUAU U ACCCCCU	1174	CAGAUUU U UCCAGAC
842	CUUUUAU A CCCCUCU	1175	AGAUGUU U CCAGACU
849	AACCCCU C CUUCAGA	1176	GAUGUUU C CAGACUU
852	CCUCCU U CAGACAC	1183	CCAGACU U CCUUGAG
853	CCUCCU C AGACACC	1184	CAGACUU C CUUGAGA
863	ACACCCU C AACCCCU	1187	ACUCCU U GAGACAC
869	UCAACCU C UUCUGGC	1208	CAGCCCU C CCAUUGG
871	AACCCU U CUGGCUC	1224	GCCAGCU C CCUCUAU
872	ACCUCUU C UGGCUPA	1228	GCUCUU C UAUUUAU
878	UCUGGCU C AAAAAGA	1230	UCCUCU A UUUADGU
890	AGAGAAU U GGGGGCU	1232	CCUCUAU U UAUGUUU
898	GGGGGCU U AGGGUUG	1233	CUUUAU U AUGUUUG
899	GGGGCUU A GGGUGGG	1234	UCUAUUU A UGUUUGC
904	UUAGGGU C GGAACCC	1238	UUUAUGU U UGCACUU
917	CCAAGCU U AGAACUU	1239	UUADGUU U GCACUUG
918	CAAGCUU A GAACUUU	1245	UUGCACU U GUGAUUA
924	UAGAAU U UAAGCAA	1251	UUGOGAU U AUUUUAU
925	AGAACUU U AAGCAAC	1252	UGUGAUU A UUUUAUA
926	GAACUUU A AGCAACA	1254	UGAUUAU U UAUUAUU
945	CACCAU U CGAAACC	1255	GAUUAUU U AUUAUUU
946	AACCAUU C GAAACCU	1256	AUUAUUU A UUAUUUA
959	CUGGGAU U CAGGAUU	1258	UAUUUAU U AUUUUAU

1259	AUUUAUU A UUUUUUU	1440	GGUUUUU U AAAAUUU
1261	UUUUUUU U UUUUUUU	1441	GUUUUUU A AAUUUUU
1262	UUUUUUU U AUUUUUU	1446	UUAAAAU A UUAUUUU
1263	AUUUUUU A UUUUUUU	1448	AAAAUUU U AUUUUUU
1265	UUUUUUU U UUUUUUU	1449	AAAUUUU A UUUUUUU
1266	AUUUUUU U AUUUUUU	1451	AUUUUUU C UUUUUUU
1267	UUUUUUU A UUUUUUU	1456	AUUUUUU U AAGUUUU
1269	UUUUUUU U AUUUUUU	1457	UUUUUUU A AGUUUUU
1270	AUUUUUU A UUUUUUU	1461	AUUUUUU U GUUUUUU
1272	UUUUUUU U UUUUUUU	1464	AAGUUUU C UAAUUUU
1273	UUUUUUU U AUUUUUU	1466	GUUUUUU A ACAAUUU
1274	AUUUUUU A UUUUUUU	1479	UUUUUUU U UUUUUUU
1276	UUUUUUU U UUUUUUU	1480	GUUUUUU U GUUUUUU
1277	AUUUUUU U AUUUUUU	1494	CAUUUUU C AUUUUUU
1278	UUUUUUU A UUUUUUU	1498	UUUUUUU C AUUUUUU
1280	UUUUUUU U UUUUUUU	1501	CAUUUUU U GUUUUUU
1281	AUUUUUU U AUUUUUU	1512	GAUUUUU C UUUUUUU
1282	UUUUUUU A UUUUUUU	1517	UUUUUUU C UUUUUUU
1294	UUUUUUU A UUUUUUU	1528	AGUUUUU U GUUUUUU
1296	AUUUUUU U UUUUUUU	1533	GUUUUUU C UUUUUUU
1297	AUUUUUU U UUUUUUU	1537	UUUUUUU A UUUUUUU
1298	UUUUUUU A UUUUUUU	1540	UUUUUUU C UUUUUUU
1300	UUUUUUU U UUUUUUU	1546	UUUUUUU A UUUUUUU
1301	AUUUUUU U UUUUUUU	1549	GUUUUUU A UUUUUUU
1315	UUUUUUU A UUUUUUU	1551	UUUUUUU C UUUUUUU
1317	UUUUUUU C UUUUUUU	1552	UUUUUUU C UUUUUUU
1334	UUUUUUU A UUUUUUU	1566	UUUUUUU A UUUUUUU
1345	UUUUUUU U UUUUUUU	1572	UUUUUUU U UUUUUUU
1350	UUUUUUU C UUUUUUU	1576	UUUUUUU U UUUUUUU
1359	UUUUUUU U UUUUUUU	1577	UUUUUUU A UUUUUUU
1360	UUUUUUU U UUUUUUU		
1361	UUUUUUU U UUUUUUU		
1362	UUUUUUU C UUUUUUU		
1386	UUUUUUU A UUUUUUU		
1393	UUUUUUU U UUUUUUU		
1394	UUUUUUU C UUUUUUU		
1401	UUUUUUU A UUUUUUU		
1414	UUUUUUU C UUUUUUU		
1422	UUUUUUU U UUUUUUU		
1423	UUUUUUU C UUUUUUU		
1425	UUUUUUU U UUUUUUU		
1426	UUUUUUU U UUUUUUU		
1427	UUUUUUU U UUUUUUU		
1431	UUUUUUU U UUUUUUU		
1432	UUUUUUU A UUUUUUU		
1436	UUUUUUU U UUUUUUU		
1437	UUUUUUU U UUUUUUU		
1438	UUUUUUU U UUUUUUU		

Table 24: Human TNF- $\alpha$  Hammerhead Ribozyme Sequences

nt. Position	HH Ribozyme Sequence
28	GGAAGAG CUGAUGAGGCCGAAAGGCCGAA ACCUGCC
29	AGGAAGA CUGAUGAGGCCGAAAGGCCGAA AACCUCC
31	AGAGGAA CUGAUGAGGCCGAAAGGCCGAA AGAACCU
33	UGAGAGG CUGAUGAGGCCGAAAGGCCGAA AGAGAAC
34	GUGAGAG CUGAUGAGGCCGAAAGGCCGAA AAGAGAA
37	UADGUGA CUGAUGAGGCCGAAAGGCCGAA AGGAAGA
39	AGUAUGU CUGAUGAGGCCGAAAGGCCGAA AGAGGAA
44	GGGUCAG CUGAUGAGGCCGAAAGGCCGAA AUGUGAG
58	GAGGGUG CUGAUGAGGCCGAAAGGCCGAA AGCGGUG
65	GGGGAGA CUGAUGAGGCCGAAAGGCCGAA AGGGGUG
67	CAGGGGA CUGAUGAGGCCGAAAGGCCGAA AGAGGGU
69	UOCAGGG CUGAUGAGGCCGAAAGGCCGAA AGAGAGG
106	CGCCCCG CUGAUGAGGCCGAAAGGCCGAA AUCADGC
136	UCUUGGG CUGAUGAGGCCGAAAGGCCGAA AGCGCCU
165	CCGCCUG CUGAUGAGGCCGAAAGGCCGAA AGCCCCU
177	GAGGAAC CUGAUGAGGCCGAAAGGCCGAA AGCACCG
180	GCUGAGG CUGAUGAGGCCGAAAGGCCGAA ACAAGCA
181	GGCUGAG CUGAUGAGGCCGAAAGGCCGAA AACAAAC
184	AGAGGCU CUGAUGAGGCCGAAAGGCCGAA AGGAACA
190	AGGAGAA CUGAUGAGGCCGAAAGGCCGAA AGGCGGA
192	GAAGGAG CUGAUGAGGCCGAAAGGCCGAA AGAGGCU
193	GGAAAGG CUGAUGAGGCCGAAAGGCCGAA AAGAGGC
195	CAGGAAG CUGAUGAGGCCGAAAGGCCGAA AGAAGAG
198	GAUCAGG CUGAUGAGGCCGAAAGGCCGAA AGGAGAA
199	CGAUCAG CUGAUGAGGCCGAAAGGCCGAA AAGGAGA
205	CUGCCAC CUGAUGAGGCCGAAAGGCCGAA AUCAGGA
226	GGCAGAA CUGAUGAGGCCGAAAGGCCGAA AGCGUGG
228	CAGGCAG CUGAUGAGGCCGAAAGGCCGAA AGAGCGU
229	GCAGGCA CUGAUGAGGCCGAAAGGCCGAA AAGAGCG
243	CACUCCA CUGAUGAGGCCGAAAGGCCGAA AGUGCAG
244	UCACUCC CUGAUGAGGCCGAAAGGCCGAA AAGUGCA
253	GGGGGCC CUGAUGAGGCCGAAAGGCCGAA AUCACUC
273	CCUGGGG CUGAUGAGGCCGAAAGGCCGAA ACUCUUC
286	UUAGAGA CUGAUGAGGCCGAAAGGCCGAA AGGUCCC
288	GAUUAGA CUGAUGAGGCCGAAAGGCCGAA AGAGSUC
290	CUGAUUA CUGAUGAGGCCGAAAGGCCGAA AGAGAGG
292	GGCUGAU CUGAUGAGGCCGAAAGGCCGAA AGAGAGA
295	GAGGGCU CUGAUGAGGCCGAAAGGCCGAA AUUAGAG
302	UGGGCCA CUGAUGAGGCCGAAAGGCCGAA AGGGCUG

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321	AGAAGAU	CUGADGAGGCCGAAAGGCCGAA	AUCUGAC
324	UCGAGAA	CUGADGAGGCCGAAAGGCCGAA	AUGAUCU
326	GUUOGAG	CUGADGAGGCCGAAAGGCCGAA	AGADGAU
327	GGUUCGA	CUGADGAGGCCGAAAGGCCGAA	AAGADCA
329	GGG GUUC	CUGADGAGGCCGAAAGGCCGAA	AGAAGAU
352	CAUGGGC	CUGADGAGGCCGAAAGGCCGAA	ACAGGCU
361	UUGCUAC	CUGADGAGGCCGAAAGGCCGAA	ACAUGGG
364	GGUUGGC	CUGADGAGGCCGAAAGGCCGAA	ACAACAU
374	UCAGCUU	CUGADGAGGCCGAAAGGCCGAA	AGGGUUU
391	GCCACUG	CUGADGAGGCCGAAAGGCCGAA	AGCUGCC
421	UGGCCAG	CUGADGAGGCCGAAAGGCCGAA	AGGGCAU
449	AGCUGGU	CUGADGAGGCCGAAAGGCCGAA	AUCUCUC
468	GCCUCU	CUGADGAGGCCGAAAGGCCGAA	AUGGCAC
480	GAUGAGG	CUGADGAGGCCGAAAGGCCGAA	ACAGGCC
484	AGUAGAU	CUGADGAGGCCGAAAGGCCGAA	AGGUACA
487	GGGAGUA	CUGADGAGGCCGAAAGGCCGAA	AUGAGGU
489	CUGGGAG	CUGADGAGGCCGAAAGGCCGAA	AGADGAG
492	GAOCUGG	CUGADGAGGCCGAAAGGCCGAA	AGUAGAU
499	UGAAGAG	CUGADGAGGCCGAAAGGCCGAA	ACCUGGG
502	CCUUGAA	CUGADGAGGCCGAAAGGCCGAA	AGGACCU
504	GCCCUUG	CUGADGAGGCCGAAAGGCCGAA	AGAGGAC
505	GGCCCUU	CUGADGAGGCCGAAAGGCCGAA	AAGAGGA
525	AUGGGUG	CUGADGAGGCCGAAAGGCCGAA	AGGGGCA
538	GGGUGAG	CUGADGAGGCCGAAAGGCCGAA	AGCACAU
541	UGUGGGU	CUGADGAGGCCGAAAGGCCGAA	AGGAGCA
553	UGCGGCU	CUGADGAGGCCGAAAGGCCGAA	AUGGUGU
562	AGACGGC	CUGADGAGGCCGAAAGGCCGAA	AUGCGGC
568	GGUAGGA	CUGADGAGGCCGAAAGGCCGAA	ACGGGCA
570	CUGGUAG	CUGADGAGGCCGAAAGGCCGAA	AGACGGC
573	GGUCUGG	CUGADGAGGCCGAAAGGCCGAA	AGGAGAC
586	GGAGGUU	CUGADGAGGCCGAAAGGCCGAA	ACCUGGG
592	CAGAGAG	CUGADGAGGCCGAAAGGCCGAA	AGGUUGA
595	UGGCAGA	CUGADGAGGCCGAAAGGCCGAA	AGGAGGU
597	GADGGCA	CUGADGAGGCCGAAAGGCCGAA	AGAGGAG
604	GGCUCUU	CUGADGAGGCCGAAAGGCCGAA	AUGGCAG
657	GGGCUCA	CUGADGAGGCCGAAAGGCCGAA	ACCAGGG
667	CCAGAUU	CUGADGAGGCCGAAAGGCCGAA	AUGGGCU
669	UCCAGAA	CUGADGAGGCCGAAAGGCCGAA	AGAUUGG
671	CCUCCCA	CUGADGAGGCCGAAAGGCCGAA	AUAGADG
682	GCUGGAA	CUGADGAGGCCGAAAGGCCGAA	ACCCCTC
684	CAGCUGG	CUGADGAGGCCGAAAGGCCGAA	AGACCCC
685	CCAGCUG	CUGADGAGGCCGAAAGGCCGAA	AAGACCC
709	CAGGCUU	CUGADGAGGCCGAAAGGCCGAA	AGUCCGU
721	GCCGAUU	CUGADGAGGCCGAAAGGCCGAA	AUCUCAG
725	UOGGGCC	CUGADGAGGCCGAAAGGCCGAA	AUUGAUC
735	GUOGAGA	CUGADGAGGCCGAAAGGCCGAA	AGUCCGG
737	AAGUCGA	CUGADGAGGCCGAAAGGCCGAA	AUAGUCC
739	CAAAGUC	CUGADGAGGCCGAAAGGCCGAA	AGAUAGU
744	CUOGGCA	CUGADGAGGCCGAAAGGCCGAA	AGUCCAG

745	ACTOGGC	CUGAUGAGGCGGAAAGGCCGAA	AAGUCGA
753	CUGOCCA	CUGAUGAGGCGGAAAGGCCGAA	ACUCGGC
763	CAAAGUA	CUGAUGAGGCGGAAAGGCCGAA	ACCUGCC
765	CCCAAAG	CUGAUGAGGCGGAAAGGCCGAA	AGACCTG
768	GADCCCA	CUGAUGAGGCGGAAAGGCCGAA	AGUAGAC
769	UGADCCC	CUGAUGAGGCGGAAAGGCCGAA	AAGUAGA
775	GGGCAAU	CUGAUGAGGCGGAAAGGCCGAA	ADCCCAA
778	ACAGGCG	CUGAUGAGGCGGAAAGGCCGAA	AUGAUCC
801	AAGGUUG	CUGAUGAGGCGGAAAGGCCGAA	ADGUUCG
808	GUUUGGG	CUGAUGAGGCGGAAAGGCCGAA	AGGUUGG
809	CGUUGGG	CUGAUGAGGCGGAAAGGCCGAA	AAGGUUG
820	GGCAGGG	CUGAUGAGGCGGAAAGGCCGAA	AGGCGUU
833	AUAAGG	CUGAUGAGGCGGAAAGGCCGAA	ADUGGGG
837	GGUADA	CUGAUGAGGCGGAAAGGCCGAA	AGGGADU
838	GGGUAAU	CUGAUGAGGCGGAAAGGCCGAA	AAGGGAU
839	GGGUAUA	CUGAUGAGGCGGAAAGGCCGAA	AAAGGGA
841	AGGGGGU	CUGAUGAGGCGGAAAGGCCGAA	AUAAGG
842	GAGGGGG	CUGAUGAGGCGGAAAGGCCGAA	AUAAGG
849	UCUGAAG	CUGAUGAGGCGGAAAGGCCGAA	AGGGGUU
852	GUGUCUG	CUGAUGAGGCGGAAAGGCCGAA	AGGAGGG
853	GGUGUCU	CUGAUGAGGCGGAAAGGCCGAA	AAGGAGG
863	AGAGGUU	CUGAUGAGGCGGAAAGGCCGAA	AGGGUGU
869	GOCAGAA	CUGAUGAGGCGGAAAGGCCGAA	AGGUUGA
871	GAGCCAG	CUGAUGAGGCGGAAAGGCCGAA	AGAGGUU
872	UGAGCCA	CUGAUGAGGCGGAAAGGCCGAA	AAGAGGU
878	UCUUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGCCAGA
890	AGCCCCC	CUGAUGAGGCGGAAAGGCCGAA	AUUCUCU
898	CGACCCU	CUGAUGAGGCGGAAAGGCCGAA	AGCCCCC
899	CGACCC	CUGAUGAGGCGGAAAGGCCGAA	AAGCCCC
904	GGGUUCC	CUGAUGAGGCGGAAAGGCCGAA	ACCCUAA
917	AAGUUCU	CUGAUGAGGCGGAAAGGCCGAA	AGCUUGG
918	AAAGUUC	CUGAUGAGGCGGAAAGGCCGAA	AAGCUUG
924	UUGCUUA	CUGAUGAGGCGGAAAGGCCGAA	AGUUCUA
925	GUUGCUU	CUGAUGAGGCGGAAAGGCCGAA	AAGUUCU
926	UGUUGCU	CUGAUGAGGCGGAAAGGCCGAA	AAAGUUC
945	GGUUCUG	CUGAUGAGGCGGAAAGGCCGAA	AGUGGUG
946	AGGUUUC	CUGAUGAGGCGGAAAGGCCGAA	AAGUGGU
959	AUUCCUG	CUGAUGAGGCGGAAAGGCCGAA	ADUCCAG
960	CAUUCU	CUGAUGAGGCGGAAAGGCCGAA	AAUCCCA
1001	GAAUUCU	CUGAUGAGGCGGAAAGGCCGAA	AGUGGUU
1007	CAGUUG	CUGAUGAGGCGGAAAGGCCGAA	AUUCUUA
1008	CCAGUUU	CUGAUGAGGCGGAAAGGCCGAA	AAUUCUU
1021	AGUUCUG	CUGAUGAGGCGGAAAGGCCGAA	AGGCCCC
1029	CCCCAGU	CUGAUGAGGCGGAAAGGCCGAA	AGUUCUG
1040	AAAGCUG	CUGAUGAGGCGGAAAGGCCGAA	AGGCCCC
1046	GGGAUCA	CUGAUGAGGCGGAAAGGCCGAA	AGCUGUA
1047	AGGGAUC	CUGAUGAGGCGGAAAGGCCGAA	AAGCUGU
1051	UGUCAGG	CUGAUGAGGCGGAAAGGCCGAA	AUCAAAG
1060	GADUCCA	CUGAUGAGGCGGAAAGGCCGAA	ADGUCAG

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1067	GUCUCCA	CUGAUGAGGCGGAAAGGCCGAA	AUUCACAG
1085	AGAACCA	CUGAUGAGGCGGAAAGGCCGAA	AGGCUCC
1086	CAGAAC	CUGAUGAGGCGGAAAGGCCGAA	AAGGCUCC
1090	UGGCCAG	CUGAUGAGGCGGAAAGGCCGAA	ACCAAAG
1091	CUGGCCA	CUGAUGAGGCGGAAAGGCCGAA	AAOCAA
1113	UCUUCUC	CUGAUGAGGCGGAAAGGCCGAA	AGUCCUG
1124	UCUAGGU	CUGAUGAGGCGGAAAGGCCGAA	AGGUUUU
1129	CAAUUUC	CUGAUGAGGCGGAAAGGCCGAA	AGGUGAG
1135	UUGUGUC	CUGAUGAGGCGGAAAGGCCGAA	AUUUUA
1151	AAGGCUU	CUGAUGAGGCGGAAAGGCCGAA	AGGUCCA
1152	GAAGGCC	CUGAUGAGGCGGAAAGGCCGAA	AAGGUCC
1158	AGAGAGG	CUGAUGAGGCGGAAAGGCCGAA	AGGCUUA
1159	GAGAGAG	CUGAUGAGGCGGAAAGGCCGAA	AAGGCUU
1162	CUGGAGA	CUGAUGAGGCGGAAAGGCCGAA	AGGAAGG
1164	AUCUGGA	CUGAUGAGGCGGAAAGGCCGAA	AGAGGAA
1166	ACAUCUG	CUGAUGAGGCGGAAAGGCCGAA	AGAGAGG
1174	GUCUGGA	CUGAUGAGGCGGAAAGGCCGAA	ACAUCUG
1175	AGUCUGG	CUGAUGAGGCGGAAAGGCCGAA	AACAUUU
1176	AAGUCUG	CUGAUGAGGCGGAAAGGCCGAA	AAACAUC
1183	CUCAAGG	CUGAUGAGGCGGAAAGGCCGAA	AGUCUGG
1184	UCUCAAG	CUGAUGAGGCGGAAAGGCCGAA	AAGUCUG
1187	GUGUCUC	CUGAUGAGGCGGAAAGGCCGAA	AGGAAGU
1208	CCADGGG	CUGAUGAGGCGGAAAGGCCGAA	AGGCUUG
1224	AUAGAGG	CUGAUGAGGCGGAAAGGCCGAA	AGCUGGC
1228	AUAAUA	CUGAUGAGGCGGAAAGGCCGAA	AGGAGGC
1230	ACAUAUA	CUGAUGAGGCGGAAAGGCCGAA	AGAGGGA
1232	AAACAUA	CUGAUGAGGCGGAAAGGCCGAA	AUAGAGG
1233	CAACAUA	CUGAUGAGGCGGAAAGGCCGAA	AUAGAGG
1234	GCAACA	CUGAUGAGGCGGAAAGGCCGAA	AAAUAGA
1238	AAGUGCA	CUGAUGAGGCGGAAAGGCCGAA	ACAUAUA
1239	CAAGUGC	CUGAUGAGGCGGAAAGGCCGAA	AACAUA
1245	UAUUCAC	CUGAUGAGGCGGAAAGGCCGAA	AGUGCAA
1251	AUAUAU	CUGAUGAGGCGGAAAGGCCGAA	AUCACAA
1252	UAUAUA	CUGAUGAGGCGGAAAGGCCGAA	AAUCACA
1254	AUAUAU	CUGAUGAGGCGGAAAGGCCGAA	AUAUAUA
1255	AAUAUAU	CUGAUGAGGCGGAAAGGCCGAA	AAUAUAU
1256	UAAUAUA	CUGAUGAGGCGGAAAGGCCGAA	AAUAUAU
1258	AAUAUAU	CUGAUGAGGCGGAAAGGCCGAA	AUAUAUA
1259	AAUAUAU	CUGAUGAGGCGGAAAGGCCGAA	AAUAUAU
1261	AUAUAUA	CUGAUGAGGCGGAAAGGCCGAA	AUAUAUA
1262	AAUAUAU	CUGAUGAGGCGGAAAGGCCGAA	AAUAUAU
1263	UAUAUAU	CUGAUGAGGCGGAAAGGCCGAA	AAUAUAU
1265	AAUAUAU	CUGAUGAGGCGGAAAGGCCGAA	AUAUAUA
1266	AAUAUAU	CUGAUGAGGCGGAAAGGCCGAA	AAUAUAU
1267	UAUAUAU	CUGAUGAGGCGGAAAGGCCGAA	AAUAUAU
1269	AAUAUAU	CUGAUGAGGCGGAAAGGCCGAA	AUAUAUA
1270	AAUAUAU	CUGAUGAGGCGGAAAGGCCGAA	AAUAUAU
1272	AUAUAUA	CUGAUGAGGCGGAAAGGCCGAA	AUAUAUA
1273	AAUAUAU	CUGAUGAGGCGGAAAGGCCGAA	AAUAUAU

1274	AAAUAAA	CUGAUGAGGCGAAAGGCGCGAA	AAAUAAU
1276	GUAAAUA	CUGAUGAGGCGAAAGGCGCGAA	AUAUAUA
1277	UGUAAAU	CUGAUGAGGCGAAAGGCGCGAA	AAUAAAU
1278	CUGUAAA	CUGAUGAGGCGAAAGGCGCGAA	AAAUAAA
1280	AUCUGUA	CUGAUGAGGCGAAAGGCGCGAA	AUAUAUA
1281	CAUCUGU	CUGAUGAGGCGAAAGGCGCGAA	AAUAAAU
1282	UCAUCUG	CUGAUGAGGCGAAAGGCGCGAA	AAAUAAA
1294	AAAUAAA	CUGAUGAGGCGAAAGGCGCGAA	ACAUAUA
1296	CCAAADA	CUGAUGAGGCGAAAGGCGCGAA	AUAUAUA
1297	CCCAAAU	CUGAUGAGGCGAAAGGCGCGAA	AAUAUAU
1298	UCCCAAA	CUGAUGAGGCGAAAGGCGCGAA	AAAUACA
1300	UCUCCCA	CUGAUGAGGCGAAAGGCGCGAA	AUAUAUA
1301	GUCUCCC	CUGAUGAGGCGAAAGGCGCGAA	AAUAAAU
1315	CCCAGGA	CUGAUGAGGCGAAAGGCGCGAA	ACCCCGG
1317	CCCCAG	CUGAUGAGGCGAAAGGCGCGAA	AUAUCCC
1334	CAGCUCU	CUGAUGAGGCGAAAGGCGCGAA	ACAUCUG
1345	CUGAGCC	CUGAUGAGGCGAAAGGCGCGAA	AGGCAGC
1350	CAUGOCU	CUGAUGAGGCGAAAGGCGCGAA	AGCCAG
1359	CACGGA	CUGAUGAGGCGAAAGGCGCGAA	ACAUGUC
1360	UCACGGA	CUGAUGAGGCGAAAGGCGCGAA	AACAUUG
1361	UUCACGG	CUGAUGAGGCGAAAGGCGCGAA	AAACAUG
1362	UUUCACG	CUGAUGAGGCGAAAGGCGCGAA	AAAACAU
1386	AACAGCC	CUGAUGAGGCGAAAGGCGCGAA	AUUGUUC
1393	ACAUGGG	CUGAUGAGGCGAAAGGCGCGAA	ACAGOCU
1394	UACAUGG	CUGAUGAGGCGAAAGGCGCGAA	AACAGCC
1401	AGGGGGC	CUGAUGAGGCGAAAGGCGCGAA	ACAUGGG
1414	AGGCACA	CUGAUGAGGCGAAAGGCGCGAA	AGGCACG
1422	UCAAAAG	CUGAUGAGGCGAAAGGCGCGAA	AGGCACA
1423	AUCRAAA	CUGAUGAGGCGAAAGGCGCGAA	AAGGCAC
1425	UAUAUCA	CUGAUGAGGCGAAAGGCGCGAA	AGAAGGC
1426	AUAUAUA	CUGAUGAGGCGAAAGGCGCGAA	AAGAAGG
1427	CAUAUUC	CUGAUGAGGCGAAAGGCGCGAA	AAAGAAG
1431	AAAACAU	CUGAUGAGGCGAAAGGCGCGAA	AUCAAAA
1432	AAAAACA	CUGAUGAGGCGAAAGGCGCGAA	AAUCAA
1436	UUUAAAA	CUGAUGAGGCGAAAGGCGCGAA	ACAUAUU
1437	UUUUAAA	CUGAUGAGGCGAAAGGCGCGAA	AACAUA
1438	AUUUUAA	CUGAUGAGGCGAAAGGCGCGAA	AAACAU
1439	UAUUUUA	CUGAUGAGGCGAAAGGCGCGAA	AAAACAU
1440	AUAUUUU	CUGAUGAGGCGAAAGGCGCGAA	AAAAACA
1441	AAUAUUU	CUGAUGAGGCGAAAGGCGCGAA	AAAAAAC
1446	CAGAUAA	CUGAUGAGGCGAAAGGCGCGAA	AUUUUAA
1448	AUCAGAU	CUGAUGAGGCGAAAGGCGCGAA	AUAUUUU
1449	AAUCAGA	CUGAUGAGGCGAAAGGCGCGAA	AAUAUUU
1451	UUAUAUA	CUGAUGAGGCGAAAGGCGCGAA	AUAUAUA
1456	ACAACUU	CUGAUGAGGCGAAAGGCGCGAA	AUCAGAU
1457	GACAACU	CUGAUGAGGCGAAAGGCGCGAA	AAUCAGA
1461	UUUAGAC	CUGAUGAGGCGAAAGGCGCGAA	ACTUAAU
1464	UUGUUUA	CUGAUGAGGCGAAAGGCGCGAA	ACAACUU
1466	CAUUGUU	CUGAUGAGGCGAAAGGCGCGAA	AGACAAC

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1479	GUCAACA	CUGADGAGGCGGAAAGGCGGAA	AUCAGCA
1480	GGUACAC	CUGADGAGGCGGAAAGGCGGAA	AADCAGC
1494	AADGAGU	CUGADGAGGCGGAAAGGCGGAA	ACAGUUG
1498	CAGCAAU	CUGADGAGGCGGAAAGGCGGAA	AGUGACA
1501	CCUCAGC	CUGADGAGGCGGAAAGGCGGAA	AUGAGUG
1512	GGGAGCA	CUGADGAGGCGGAAAGGCGGAA	AGGCGUC
1517	CCGCGG	CUGADGAGGCGGAAAGGCGGAA	AGCAGAG
1528	CAGACAC	CUGADGAGGCGGAAAGGCGGAA	ACGCGCU
1533	GAUACA	CUGADGAGGCGGAAAGGCGGAA	ACACAAC
1537	GGCGAU	CUGADGAGGCGGAAAGGCGGAA	ACAGACA
1540	GUAGGCC	CUGADGAGGCGGAAAGGCGGAA	ADUACAG
1546	UGAAUAG	CUGADGAGGCGGAAAGGCGGAA	AGGCGGA
1549	CACUGAA	CUGADGAGGCGGAAAGGCGGAA	AGUAGGC
1551	GCCACUG	CUGADGAGGCGGAAAGGCGGAA	ADAGUAG
1552	CGCCACU	CUGADGAGGCGGAAAGGCGGAA	AUAAGUA
1566	CAACCUU	CUGADGAGGCGGAAAGGCGGAA	ADUUCUC
1572	CCUAGC	CUGADGAGGCGGAAAGGCGGAA	ACCUUUA
1576	CUUCCU	CUGADGAGGCGGAAAGGCGGAA	AGCAACC
1577	UCUUUCC	CUGADGAGGCGGAAAGGCGGAA	AAGCAAC

Table 25: Mouse TNF-a HH Target Sequences

nt. Position	HH Target Sequence	nt. Position	HH Target Sequence
66	UgGAAAU a GcuCCa	324	GgGUGAU C GGuCCCC
101	GGCAGGU U CUgUcCC	347	GAGAagU u cCCAAaU
101	GGCAGgU u CuGUcC	364	CCUCcCU C UCADUCAG
102	GCAGGUU C UgUcCCU	366	UCcCCU c AUCAGuu
102	gCAGgUU c ugUCCCU	366	UcCCCUU C auCAGU
106	GUUCgU c CCUUCa	369	CCUCcAU C AGuuCUa
110	UgUcCCU u UCACuCa	376	CAGuuCU a UGGCCCA
111	gUCcCUU u CaCUcAC	390	AgACCCU C AcaCUcA
111	guCCCUU u CACuCAc	396	ucaCAcU c AGAUCAU
112	UcCCUuU C ACuCAcU	401	cUCAGAU C ADCUUCU
116	UuUCACU C AcUGgcc	404	AGADCAU C UUCUCaA
137	GCCaCAU C uCCcUCc	406	ADCADCU U CCaAAa
139	caCAuCU C CCUCcAg	406	AUCADcU U cUcaAAA
177	GCAUGAU C CGcGACG	407	UCAUCUU C UCaaAau
207	AGGCaCU C CCCaAaA	409	ADCUCUU C aAAauuC
228	GGGGQuU C CAGAACU	409	AuCuUCU c AaAAUUC
228	GGGGQuU c CAGaacU	409	aUcUUCU c AAAauUc
236	CAGaaCU C CAGGCGG	432	AGCCUGU A GCCCACG
236	CAGaACU c cAGgcGg		
249	GGugCCU a UgUCUcA		
249	GGuGCCU a UGuCUa	444	AcGUcGU A GCAAACC
		501	AcGCCCU C CUGGCA
261	UCAGCCU C UUCUCaU	560	gGgUUGU a CCUguc
261	UCAgCCU C UUCUcau	560	GGguUGU A CCUgUC
263	AGCCUCU U UCuAUUC	564	UGUAACU u gUCUAU
263	AgCCUCU U UCuAUUC	567	ACCUgU C UACUCCC
264	GCCUCUU C UCuAUUC	569	CUgUCU A CUCCCAG
264	gCCUCUU C UCuAUUC	572	gUCUAU C CCAGGUu
266	CCUCUUU C aUUCUUG	572	GUCUaCU c CCAGguu
269	UUCUCaU U CCUGcUu	572	GuCUaCU C CCAGGUu
270	UCUCaUU C CUGcUuG	579	CCCAGGU u CUUUCA
276	UCCUGcU u GUGGCAG	580	CCAGguU c uCUUcAa
297	CCACGCU C UUCUGuC	580	CCAGguU c UCuUcAa
299	ACGCUUU U CUGuCUa	582	AGGUUUU C UUCaagg
300	CGCUUUU C UGUCUaC	582	AGGUUUU C UUCAAGG
304	CUuCUgU c uAcUGaa	584	GUuCUUU U CAAGGGA
306	UcUGUcU a cUGAAcU	585	UuCUUUU C AAGGGaC
314	CUGaACU U cGGgGUG	608	CcCGaCU a CgugUCU
315	UGaACUU c GGgGUGA	615	aCgUGcU C CUCAcCC
315	uGaaCUU c GGgguGa	615	AcGUGCU C CUCAcCC
324	gGGUGaU c GgUCCcC	618	UGUCUU C ACCACA

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630	ACACCgU C AGCCGau	940	GuCUAaU c cUCAGaG
630	ACACCgU C AgCCGaU	943	UACUccU C AGaGcCc
638	agcCgAU u uGCUaUc	972	UCUazCU u AgAAAAGg
643	aUUUGcU a uCUcAuA	972	ucUazCU u AGAaAgG
645	UuGCUaU C UCaUACC	973	CUaACuU A GAAAggG
647	GUaUcU C aUACCAg	984	AGgGgAU U auGGcuc
663	agAAaGU C AACCUCC	984	AGGGgaU U aUgGCUc
669	UCAACU C CUCUCUG	985	GGGGuU a uGGcUCa
669	UcAAccU c cUcUCUG	997	UcAGaGU c CAACucU
672	ACCUCCU C UCUGCCg	1010	CugUGCU c AGAGCUU
674	CUCCUcU C UGCCgUC	1017	cAGAgCU U UcAaCAA
681	cUGCCgU C AagaGcC	1018	AGAgCUU U cAaCAAC
681	CGCCgU C AAGAGCC	1019	GAgCUU c AaCAACu
681	CUGcCgU C aaGAgcC	1073	UgGGCCU c ucAUgCA
734	CCCUGGU C UGAGCCC	1096	AAgGAcU C AAaugGG
734	CccUGGU a ugaGCCc	1106	aUGGGcU U uccGAaU
744	AGCCCAU a UAcCUGG	1107	UGGGcUU u ccGAADu
746	CCCAaU A cCUGGGA	1108	GGgCUU c cGaaUUC
759	GAgGAGU C uuCCAGc	1115	CcGAaU C ACUGGzG
759	GAGGaGU C UUCACG	1133	CGAAugU C CAuuCcU
761	GGaGUcU U CCAGCUG	1164	gagUGgU c AgGUUGc
762	GaGUcUU C CAGCUGG	1180	UcUgUcU c agaAUGA
786	ACCaACU C AGCCGUG	1203	aaGAuCU c AGGCCUU
798	CUGAgGU C AAUCuGC	1210	cAGGCCU U CCUzccU
802	GgUcAU C uGCCaA	1211	AGGCCUU C CUacCUu
812	CCCaAgU A cuUaGAC	1214	CCUUCUU a cCUuCAG
816	AgUAcuU a GACUUUG	1218	CcuACcU u CaGAOCu
821	uUaGACU U UGcGAG	1218	CCzccU U CAGACcu
822	UaGACUU U GCgGAGU	1218	cCuACcU u cAgACCU
830	GCgGAGU C cGGGCAG	1218	CCUacCU u CAGaccU
840	GGCAGGU C UACUUUG	1219	CUzCCUU C AGACcuu
842	CAGGOCU A CUUUGGa	1219	CUAcCUU c agACcUU
842	CAGgucU a CUUugGA	1226	CagACCU U uCCAgAC
842	cagGuCU a CUUUGGA	1226	CAGAcCU U UCCAGAC
845	GUcUAU U UGgagUC	1227	agACCUU u CCAGAcU
846	UcUAaU U GGagUCA	1227	AGAcCUU U CCAGAcU
852	UUGgagU C AUUGCuC	1228	GAccUUU C CAGAcUc
855	GagUCAU U GCUUGU	1238	gACUcuU c cCUGAGG
887	AUCCaUU c ucUACCC	1262	CAGCCuU C CuCAcG
891	AuuCuCU a CCCaGCC	1283	CCCCccU C uaUUUAU
905	CCcCaCU C UgaCCCC	1283	cCcCCCU C UAUUUAU
905	cCCCaCU c UgACCCC	1285	cCCCUU A UUUAaU
905	CcCCACU c uGAcCC	1287	CcuCUAU u UauAuUU
914	GAcCCcU U uacUCUG	1287	CCUCUAU U UAaUUU
915	ACCCCuU u acUCuGA	1288	CUcUAU U AUaUUUG
919	CUUUAcU c ugaCCcC	1289	UCUAUUU A UzUUUGC
928	GAcCCcU u UaUugUC	1293	UUUAaU U UGCACUU
928	gAcCCCU U UAUUGuC	1293	uUUaUaU u UGcAcUu
932	CCUUUAU U guQuaCU	1294	UUUAaU U GCACUa

1300	UUGCACU U aUuADu	1462	aCCuUGU u GCCuCCU
1303	CACuDaU u AuDuAUU	1470	GccuCcU C UUUUGcU
1304	acDuAUU A UUUADUA	1472	cuCcCCU U UUGcUUA
1306	UuAUUAU U UAUAUAU	1473	uCcCCUU U UGcUUAU
1307	uADUAUU U AUUAUUU	1474	CcCCUUU U GcUUADG
1307	UaUUAUU U AuuADuU	1478	UUUUGcU U AUGUUUA
1308	AUAUAUU A UUAUUUA	1479	UUUGcUU a UGuuAA
1310	UauDuAU U AUUAUAU	1479	UUUGcUU A UGUUUaa
1310	UAUUUAU U AUUAUAU	1484	UUAUGUU U aaaAcAA
1310	UAUUUAU U AUUAUAU	1498	AAAuauU U AUUUaAc
1311	AUUUAUU A UUUUAUU	1511	AcCCaAU U GUUUAA
1311	AUUUAUU A UUUUAUU	1514	cAAUUUGU C UuAAuAA
1311	AuuUAUU A UuUauUU	1516	aUUUGUU u AAuAAcG
1313	UUAUUUAU U UAUAUAU	1529	CgcugAU u UGUgAC
1313	UUAUUUAU U UAUAUAU	1529	cGUUGAU U UGUUGAC
1313	uUAUUUAU u UauUUAu	1530	gCUGAUU u gGUgacC
1314	UAUAUAU U AUUAUAU	1530	GUUGAUU U GUUGACC
1314	UAUAUAU U AUUAUAU	1563	UgaAcCU c UGcUCCC
1315	AUAUAUU A UUAUAUA	1563	ugaaCCU C UGUUUCC
1317	UAUAUAU U UAUAUAU	1568	CUUGCU C CCCAcGG
1318	AUUUAUU U AUUAUUU	1589	UGaCUGU A AUuGcCC
1319	UUUAUUU A UUAUUUA	1592	CUGUAAU u GcCCUAC
1326	AUAUAUU A UUAUUUU	1617	GAGAAAU A AAGaUcG
1328	UAUUUAU U UAUUUgC	1623	UAAAGaU c GCUUAaa
1329	AUUUAUU U AUUUgCu	1633	UUaazaU a aaAAaCC
1330	UUUAUUU A UUUgCu	25	AgGgaCU a gCCagGA
1332	UAUUUAU U UgCuUAU		
1333	AUUUAUU U gCuUAUG		
1337	auUUUCU U AuGAAuG		
1338	uUUUGCU A uGAAuGu		
1346	UGAAUGU A UUAUUUU		
1348	AAUGUAU U UAUUUGG		
1349	AUGUAUU U AUUUUGa		
1350	UGUAUUU A UUUUGGa		
1352	uAUuUAU u UGGaAGG		
1352	UAUUUAU U UGGaAGg		
1353	AUUUAUU U GGaAGgC		
1369	GGGUGU C CUUGaGG		
1398	gCUguCU U cAGACAg		
1398	GCUguCU U cagaCAG		
1412	GACADGU U UUCuGUG		
1413	ACADGUU U UCuGUGA		
1414	CADGUUU U CuGUGAA		
1415	AUGUUUU C uGUGAAA		
1415	AUGUUUU c UgugAAa		
1438	gaGCGGU c CCCAccU		
1451	CUGGCCU C UcUaCCU		
1453	ggCCCCU C UaCCuUG		

Table 26: Mouse TNF- $\alpha$  Hammerhead Ribozyme Sequences

nt. Position	Mouse HH Ribozyme Sequence
25	UCCUGGC CUGAUGAGGCOGAAAGGCCGAA AGUCCCU
66	UGGAGC CUGAUGAGGCOGAAAGGCCGAA AUUUCOA
101	GGGACAG CUGAUGAGGCOGAAAGGCCGAA ACCUGCC
101	GGGACAG CUGAUGAGGCOGAAAGGCCGAA ACCUGCC
102	AGGGACA CUGAUGAGGCOGAAAGGCCGAA AACCUCC
102	AGGGACA CUGAUGAGGCOGAAAGGCCGAA AACCUCC
106	UGAAAGG CUGAUGAGGCOGAAAGGCCGAA ACAGAAC
110	UGAGUGA CUGAUGAGGCOGAAAGGCCGAA AGGACA
111	GUGAGUG CUGAUGAGGCOGAAAGGCCGAA AAGGAC
111	GUGAGUG CUGAUGAGGCOGAAAGGCCGAA AAGGAC
112	AGUGAGU CUGAUGAGGCOGAAAGGCCGAA AAAGGA
116	GGCCAGU CUGAUGAGGCOGAAAGGCCGAA AGUGAAA
137	GGAGGA CUGAUGAGGCOGAAAGGCCGAA AUGGGC
139	CUGAGG CUGAUGAGGCOGAAAGGCCGAA AGADUG
177	CGUCGG CUGAUGAGGCOGAAAGGCCGAA AUCADGC
207	UUUGGG CUGAUGAGGCOGAAAGGCCGAA AGUGCCU
228	AGUUCUG CUGAUGAGGCOGAAAGGCCGAA AAGCCCC
228	AGUUCUG CUGAUGAGGCOGAAAGGCCGAA AAGCCCC
236	CCGCCUG CUGAUGAGGCOGAAAGGCCGAA AGUUCUG
236	CCGCCUG CUGAUGAGGCOGAAAGGCCGAA AGUUCUG
249	UGAGACA CUGAUGAGGCOGAAAGGCCGAA AGGCACC
249	UGAGACA CUGAUGAGGCOGAAAGGCCGAA AGGCACC
261	AUGAGAA CUGAUGAGGCOGAAAGGCCGAA AGGCUA
261	AUGAGAA CUGAUGAGGCOGAAAGGCCGAA AGGCUA
263	GAUAG CUGAUGAGGCOGAAAGGCCGAA AGAGGU
263	GAUAG CUGAUGAGGCOGAAAGGCCGAA AGAGGU
264	GGAAUGA CUGAUGAGGCOGAAAGGCCGAA AAGAGGC
264	GGAAUGA CUGAUGAGGCOGAAAGGCCGAA AAGAGGC
266	CAGGAU CUGAUGAGGCOGAAAGGCCGAA AGAAGAG
269	AAGCAG CUGAUGAGGCOGAAAGGCCGAA AUGAGAA
270	CAAGCAG CUGAUGAGGCOGAAAGGCCGAA AUAGAGA
276	CUGCCAC CUGAUGAGGCOGAAAGGCCGAA AGCAGGA
297	GACAGAA CUGAUGAGGCOGAAAGGCCGAA AGCGUGG
299	UAGACAG CUGAUGAGGCOGAAAGGCCGAA AGAGGU
300	GUAGACA CUGAUGAGGCOGAAAGGCCGAA AAGAGCG
304	UUCAGUA CUGAUGAGGCOGAAAGGCCGAA ACAGAAG
306	AGUUCAG CUGAUGAGGCOGAAAGGCCGAA AGACAGA
314	CACCCCG CUGAUGAGGCOGAAAGGCCGAA AGUUCAG
315	UCACCC CUGAUGAGGCOGAAAGGCCGAA AAGUUA

315	UACCCC	CUGAUGAGGCGGAAAGGCGGAA	AAGGUCA
324	GGGGACC	CUGAUGAGGCGGAAAGGCGGAA	AUCACCC
324	GGGGACC	CUGAUGAGGCGGAAAGGCGGAA	AUCACCC
347	AUUUGGG	CUGAUGAGGCGGAAAGGCGGAA	ACUUCUC
364	CUGAUGA	CUGAUGAGGCGGAAAGGCGGAA	AGGGAGG
366	AACUGAU	CUGAUGAGGCGGAAAGGCGGAA	AGAGGGA
366	AACUGAU	CUGAUGAGGCGGAAAGGCGGAA	AGAGGGA
369	UAGAACT	CUGAUGAGGCGGAAAGGCGGAA	AUGAGAG
376	UGGGCCA	CUGAUGAGGCGGAAAGGCGGAA	AGAACCG
390	UGAGUGU	CUGAUGAGGCGGAAAGGCGGAA	AGGGGCU
396	AUGAUCU	CUGAUGAGGCGGAAAGGCGGAA	AGGUGGA
401	AGAAGAU	CUGAUGAGGCGGAAAGGCGGAA	AUCGCGG
404	UUGAGAA	CUGAUGAGGCGGAAAGGCGGAA	AUGAUCU
406	UUUUGAG	CUGAUGAGGCGGAAAGGCGGAA	AGADGAU
406	UUUUGAG	CUGAUGAGGCGGAAAGGCGGAA	AGADGAU
407	AUUUGGA	CUGAUGAGGCGGAAAGGCGGAA	AAGAUGA
409	GAUUUUU	CUGAUGAGGCGGAAAGGCGGAA	AGAAGAU
409	GAUUUUU	CUGAUGAGGCGGAAAGGCGGAA	AGAAGAU
409	GAUUUUU	CUGAUGAGGCGGAAAGGCGGAA	AGAAGAU
432	CGGGGGC	CUGAUGAGGCGGAAAGGCGGAA	ACAGGCU
444	GGUUUGC	CUGAUGAGGCGGAAAGGCGGAA	ACGACGU
501	UGGOCAG	CUGAUGAGGCGGAAAGGCGGAA	AGGGGCU
560	GACAAGG	CUGAUGAGGCGGAAAGGCGGAA	ACAAACC
560	GACAAGG	CUGAUGAGGCGGAAAGGCGGAA	ACAAACC
564	AGUAGAC	CUGAUGAGGCGGAAAGGCGGAA	AGGUACA
567	GGGAGUA	CUGAUGAGGCGGAAAGGCGGAA	ACAAGGU
569	CUGGGAG	CUGAUGAGGCGGAAAGGCGGAA	AGACAAG
572	AACUUGG	CUGAUGAGGCGGAAAGGCGGAA	AGUAGAC
572	AACUUGG	CUGAUGAGGCGGAAAGGCGGAA	AGUAGAC
572	AACUUGG	CUGAUGAGGCGGAAAGGCGGAA	AGUAGAC
579	UGAAGAG	CUGAUGAGGCGGAAAGGCGGAA	ACCUUGG
580	UUGAAGA	CUGAUGAGGCGGAAAGGCGGAA	AACUUGG
580	UUGAAGA	CUGAUGAGGCGGAAAGGCGGAA	AACUUGG
582	CCUUGAA	CUGAUGAGGCGGAAAGGCGGAA	AGAACCU
582	CCUUGAA	CUGAUGAGGCGGAAAGGCGGAA	AGAACCU
584	UCCCUUG	CUGAUGAGGCGGAAAGGCGGAA	AGAGAAC
585	GUCCCUU	CUGAUGAGGCGGAAAGGCGGAA	AAGAGAA
608	GAGCACG	CUGAUGAGGCGGAAAGGCGGAA	AGUOGGG
615	GGGUGAG	CUGAUGAGGCGGAAAGGCGGAA	AGCACGU
615	GGGUGAG	CUGAUGAGGCGGAAAGGCGGAA	AGCACGU
618	UGUGGGU	CUGAUGAGGCGGAAAGGCGGAA	AGGAGCA
630	AUCGGCU	CUGAUGAGGCGGAAAGGCGGAA	ACGGUGU
630	AUCGGCU	CUGAUGAGGCGGAAAGGCGGAA	ACGGUGU
638	GATAGCA	CUGAUGAGGCGGAAAGGCGGAA	AUCGGCU
643	UAUGAGA	CUGAUGAGGCGGAAAGGCGGAA	AGCAAAU
645	GGUAUGA	CUGAUGAGGCGGAAAGGCGGAA	AUAGCAA
647	CUGGUAU	CUGAUGAGGCGGAAAGGCGGAA	AGATAGC

663	GGAGGUU	CUGAUGAGGCGGAAAGGCCGAA	ACUUUCU
669	CAGAGAG	CUGAUGAGGCGGAAAGGCCGAA	AGGUUGA
669	CAGAGAG	CUGAUGAGGCGGAAAGGCCGAA	AGGUUGA
672	CGGCAGA	CUGAUGAGGCGGAAAGGCCGAA	AGGAGGU
674	GACGGCA	CUGAUGAGGCGGAAAGGCCGAA	AGAGGAG
681	GGCUCUU	CUGAUGAGGCGGAAAGGCCGAA	ACGGCAG
681	GGCUCUU	CUGAUGAGGCGGAAAGGCCGAA	ACGGCAG
681	GGCUCUU	CUGAUGAGGCGGAAAGGCCGAA	ACGGCAG
734	GGGCUCA	CUGAUGAGGCGGAAAGGCCGAA	AACAGGG
734	GGGCUCA	CUGAUGAGGCGGAAAGGCCGAA	AACAGGG
744	CCAGGUA	CUGAUGAGGCGGAAAGGCCGAA	AUGGGGU
746	UCCGAGG	CUGAUGAGGCGGAAAGGCCGAA	AUAAGGG
759	GCUGGAA	CUGAUGAGGCGGAAAGGCCGAA	ACUCCGC
759	GCUGGAA	CUGAUGAGGCGGAAAGGCCGAA	ACUCCGC
761	CAGCUGG	CUGAUGAGGCGGAAAGGCCGAA	AGACGCC
762	CCAGCUG	CUGAUGAGGCGGAAAGGCCGAA	AAGACGC
786	CAGCGCU	CUGAUGAGGCGGAAAGGCCGAA	AGUUGGU
798	GCAGAUU	CUGAUGAGGCGGAAAGGCCGAA	AACUCCG
802	UUGGGCA	CUGAUGAGGCGGAAAGGCCGAA	AUUGACC
812	GUUUAAG	CUGAUGAGGCGGAAAGGCCGAA	ACUUGGG
816	CAAAGUC	CUGAUGAGGCGGAAAGGCCGAA	AAGUACU
821	CUCCGCA	CUGAUGAGGCGGAAAGGCCGAA	AGUCCUA
822	ACUCCGC	CUGAUGAGGCGGAAAGGCCGAA	AAGUCUA
830	CUCCCGG	CUGAUGAGGCGGAAAGGCCGAA	ACUCCGC
840	CAAAGUA	CUGAUGAGGCGGAAAGGCCGAA	ACUCCGC
842	UCCAAAG	CUGAUGAGGCGGAAAGGCCGAA	AGACCCG
842	UCCAAAG	CUGAUGAGGCGGAAAGGCCGAA	AGACCCG
842	UCCAAAG	CUGAUGAGGCGGAAAGGCCGAA	AGACCCG
845	GACUCCA	CUGAUGAGGCGGAAAGGCCGAA	AGUAGAC
846	UGACUCC	CUGAUGAGGCGGAAAGGCCGAA	AAGUAGA
852	GAGCAAU	CUGAUGAGGCGGAAAGGCCGAA	ACUCCCA
855	ACAGAGC	CUGAUGAGGCGGAAAGGCCGAA	AUGACUC
887	GGGUAGA	CUGAUGAGGCGGAAAGGCCGAA	AADGGAU
891	GGCUGGG	CUGAUGAGGCGGAAAGGCCGAA	AGAGAAU
905	GGGGUCA	CUGAUGAGGCGGAAAGGCCGAA	AGUGGGG
905	GGGGUCA	CUGAUGAGGCGGAAAGGCCGAA	AGUGGGG
905	GGGGUCA	CUGAUGAGGCGGAAAGGCCGAA	AGUGGGG
914	CAGAGUA	CUGAUGAGGCGGAAAGGCCGAA	AGGGGUC
915	UCAGAGU	CUGAUGAGGCGGAAAGGCCGAA	AAGGGGU
919	GGGGUCA	CUGAUGAGGCGGAAAGGCCGAA	AGUAAAG
928	GACAAUA	CUGAUGAGGCGGAAAGGCCGAA	AGGGGUC
928	GACAAUA	CUGAUGAGGCGGAAAGGCCGAA	AGGGGUC
932	AGUAGAC	CUGAUGAGGCGGAAAGGCCGAA	AUAAGAG
940	CUUGAG	CUGAUGAGGCGGAAAGGCCGAA	AGUAGAC
943	GGGCUUU	CUGAUGAGGCGGAAAGGCCGAA	AGGAGUA
972	CCUUUCU	CUGAUGAGGCGGAAAGGCCGAA	AGUUAGA
972	CCUUUCU	CUGAUGAGGCGGAAAGGCCGAA	AGUUAGA
973	CCUUUUC	CUGAUGAGGCGGAAAGGCCGAA	AAGUUAG
984	GAGCCAU	CUGAUGAGGCGGAAAGGCCGAA	AUCCCCU

984	GAGCCAU	CUGAUGAGGCGGAAAGGCCGAA	AUCUUUU
985	UGAGCCA	CUGAUGAGGCGGAAAGGCCGAA	AUUCUUU
997	AGAGUUG	CUGAUGAGGCGGAAAGGCCGAA	ACUCUGA
1010	AAGCUCU	CUGAUGAGGCGGAAAGGCCGAA	AGCACAG
1017	UUGUUGA	CUGAUGAGGCGGAAAGGCCGAA	AGCUCUG
1018	GUUGUUG	CUGAUGAGGCGGAAAGGCCGAA	AAGCUCU
1019	AGUUGUU	CUGAUGAGGCGGAAAGGCCGAA	AAAGCUC
1073	UGCAUGA	CUGAUGAGGCGGAAAGGCCGAA	AGGCUCA
1096	CCCAUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUCCUU
1106	AUUCGGA	CUGAUGAGGCGGAAAGGCCGAA	AGCCCAU
1107	AAUUCGG	CUGAUGAGGCGGAAAGGCCGAA	AAGCCCA
1108	GAAUUCG	CUGAUGAGGCGGAAAGGCCGAA	AAAGCCC
1115	CUCCAGU	CUGAUGAGGCGGAAAGGCCGAA	AAUUCGG
1133	AGGAUUG	CUGAUGAGGCGGAAAGGCCGAA	ACAUUCG
1164	GCAACCU	CUGAUGAGGCGGAAAGGCCGAA	AGCACUC
1180	UCAUUCU	CUGAUGAGGCGGAAAGGCCGAA	AGACAGA
1203	AAGGCCU	CUGAUGAGGCGGAAAGGCCGAA	AGAUUCU
1210	AGGUAGG	CUGAUGAGGCGGAAAGGCCGAA	AGGCCUG
1211	AAGGUAG	CUGAUGAGGCGGAAAGGCCGAA	AAGGCCU
1214	CUGAAGG	CUGAUGAGGCGGAAAGGCCGAA	AGGAAGG
1218	AGGUUCG	CUGAUGAGGCGGAAAGGCCGAA	AGGUAGG
1218	AGGUUCG	CUGAUGAGGCGGAAAGGCCGAA	AGGUAGG
1218	AGGUUCG	CUGAUGAGGCGGAAAGGCCGAA	AGGUAGG
1218	AGGUUCG	CUGAUGAGGCGGAAAGGCCGAA	AGGUAGG
1219	AAGGUCT	CUGAUGAGGCGGAAAGGCCGAA	AAGGUAG
1219	AAGGUCT	CUGAUGAGGCGGAAAGGCCGAA	AAGGUAG
1226	GUCUGGA	CUGAUGAGGCGGAAAGGCCGAA	AGGUUCG
1226	GUCUGGA	CUGAUGAGGCGGAAAGGCCGAA	AGGUUCG
1227	AGUCUGG	CUGAUGAGGCGGAAAGGCCGAA	AAGGUCT
1227	AGUCUGG	CUGAUGAGGCGGAAAGGCCGAA	AAGGUCT
1228	GAGUCUG	CUGAUGAGGCGGAAAGGCCGAA	AAAGGUC
1238	CCUCAGG	CUGAUGAGGCGGAAAGGCCGAA	AAGAGUC
1262	CUGUGAG	CUGAUGAGGCGGAAAGGCCGAA	AAGGUCG
1283	AUAUAAU	CUGAUGAGGCGGAAAGGCCGAA	AGGGGGG
1283	AUAUAAU	CUGAUGAGGCGGAAAGGCCGAA	AGGGGGG
1285	AUAUAAA	CUGAUGAGGCGGAAAGGCCGAA	AGAGGGG
1287	AAAUAAU	CUGAUGAGGCGGAAAGGCCGAA	AUAAGAG
1287	AAAUAAU	CUGAUGAGGCGGAAAGGCCGAA	AUAAGAG
1288	CRAAUUU	CUGAUGAGGCGGAAAGGCCGAA	AAUAGAG
1289	GCAUAAU	CUGAUGAGGCGGAAAGGCCGAA	AAAUAGA
1293	AAGUGCA	CUGAUGAGGCGGAAAGGCCGAA	AUAUAAA
1293	AAGUGCA	CUGAUGAGGCGGAAAGGCCGAA	AUAUAAA
1294	UAAGUCC	CUGAUGAGGCGGAAAGGCCGAA	AAUAAUA
1300	AAAUAAU	CUGAUGAGGCGGAAAGGCCGAA	AGUGCAA
1303	AAUAAAU	CUGAUGAGGCGGAAAGGCCGAA	AUAAGUG
1304	UAUAAUA	CUGAUGAGGCGGAAAGGCCGAA	AAUAGU
1306	AAUAAUA	CUGAUGAGGCGGAAAGGCCGAA	AUAUAAA
1307	AAAUAAU	CUGAUGAGGCGGAAAGGCCGAA	AAUAAUA
1307	AAAUAAU	CUGAUGAGGCGGAAAGGCCGAA	AAUAAUA

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1308	UAAATAA	CUGAUGAGGCCGAAAGGCCGAA	AAATAAU
1310	AAUAAAU	CUGAUGAGGCCGAAAGGCCGAA	AUAAADA
1310	AAUAAAU	CUGAUGAGGCCGAAAGGCCGAA	AUAAADA
1310	AAUAAAU	CUGAUGAGGCCGAAAGGCCGAA	AUAAADA
1311	AAATAAA	CUGAUGAGGCCGAAAGGCCGAA	AAATAAU
1311	AAATAAA	CUGAUGAGGCCGAAAGGCCGAA	AAATAAU
1311	AAATAAA	CUGAUGAGGCCGAAAGGCCGAA	AAATAAU
1313	AUAAADA	CUGAUGAGGCCGAAAGGCCGAA	AUAAADA
1313	AUAAADA	CUGAUGAGGCCGAAAGGCCGAA	AUAAADA
1313	AUAAADA	CUGAUGAGGCCGAAAGGCCGAA	AUAAADA
1314	AAUAAAU	CUGAUGAGGCCGAAAGGCCGAA	AAUAAAU
1314	AAUAAAU	CUGAUGAGGCCGAAAGGCCGAA	AAUAAAU
1315	UAAATAA	CUGAUGAGGCCGAAAGGCCGAA	AAATAAU
1317	AAUAAUA	CUGAUGAGGCCGAAAGGCCGAA	AUAAACA
1318	AAATAAU	CUGAUGAGGCCGAAAGGCCGAA	AAATAAU
1319	UAAATAA	CUGAUGAGGCCGAAAGGCCGAA	AAATAAA
1325	AAATAAA	CUGAUGAGGCCGAAAGGCCGAA	AAATAAU
1328	GCAATAA	CUGAUGAGGCCGAAAGGCCGAA	AUAAADA
1329	AGCAAAU	CUGAUGAGGCCGAAAGGCCGAA	AAATAAU
1330	AAGCAAA	CUGAUGAGGCCGAAAGGCCGAA	AAATAAA
1332	AUAAGCA	CUGAUGAGGCCGAAAGGCCGAA	AUAAADA
1333	CAUAAGC	CUGAUGAGGCCGAAAGGCCGAA	AAATAAU
1337	CAUUCAU	CUGAUGAGGCCGAAAGGCCGAA	AGCAAAU
1338	ACAUTCA	CUGAUGAGGCCGAAAGGCCGAA	AAGCAAA
1346	AAATAAA	CUGAUGAGGCCGAAAGGCCGAA	ACAUTCA
1348	CCAAADA	CUGAUGAGGCCGAAAGGCCGAA	AUACAUT
1349	UCCAAAU	CUGAUGAGGCCGAAAGGCCGAA	AAUACAU
1350	UCCCAAA	CUGAUGAGGCCGAAAGGCCGAA	AAATACA
1352	CCUCCCA	CUGAUGAGGCCGAAAGGCCGAA	AUAAADA
1352	CCUCCCA	CUGAUGAGGCCGAAAGGCCGAA	AUAAADA
1353	GCCUCC	CUGAUGAGGCCGAAAGGCCGAA	AAUAAAU
1369	CCUCCAG	CUGAUGAGGCCGAAAGGCCGAA	ACAACCC
1398	CUGUCUG	CUGAUGAGGCCGAAAGGCCGAA	AGACAGC
1398	CUGUCUG	CUGAUGAGGCCGAAAGGCCGAA	AGACAGC
1412	CACAGAA	CUGAUGAGGCCGAAAGGCCGAA	ACADGUC
1413	UCACAGA	CUGAUGAGGCCGAAAGGCCGAA	AACADGU
1414	UUCACAG	CUGAUGAGGCCGAAAGGCCGAA	AAACADG
1415	UUUCACA	CUGAUGAGGCCGAAAGGCCGAA	AAACAUU
1415	UUUCACA	CUGAUGAGGCCGAAAGGCCGAA	AAACAUU
1438	AGGCGGG	CUGAUGAGGCCGAAAGGCCGAA	ACAGCUC
1451	AGGUAGA	CUGAUGAGGCCGAAAGGCCGAA	AGGCCAG
1453	CAAGGUA	CUGAUGAGGCCGAAAGGCCGAA	AGAGGCC
1455	AACAAGG	CUGAUGAGGCCGAAAGGCCGAA	AGAGAGG
1462	AGGAGGC	CUGAUGAGGCCGAAAGGCCGAA	ACAAGGU
1470	AGCAAAA	CUGAUGAGGCCGAAAGGCCGAA	AGGAGGC
1472	UAAGCAA	CUGAUGAGGCCGAAAGGCCGAA	AGAGGAG
1473	AUAAGCA	CUGAUGAGGCCGAAAGGCCGAA	AAGAGGA
1474	CAUAAGC	CUGAUGAGGCCGAAAGGCCGAA	AAAGAGG
1478	UAAACAU	CUGAUGAGGCCGAAAGGCCGAA	AGCAAAA

1479	UUAAACA	CUGADGAGGCCGAAAGGCCGAA	AAGCAAA
1479	UUAAACA	CUGADGAGGCCGAAAGGCCGAA	AAGCAAA
1484	UUGUUUU	CUGADGAGGCCGAAAGGCCGAA	AACAUA
1498	GUUAGAU	CUGADGAGGCCGAAAGGCCGAA	AAUAUUU
1511	UUAAGAC	CUGADGAGGCCGAAAGGCCGAA	AUUGGGU
1514	UUAUUAA	CUGADGAGGCCGAAAGGCCGAA	ACAAUUG
1516	CGUUUUU	CUGADGAGGCCGAAAGGCCGAA	AGACAAU
1529	GUCAACA	CUGADGAGGCCGAAAGGCCGAA	AUCAGCG
1529	GUCAACA	CUGADGAGGCCGAAAGGCCGAA	AUCAGCG
1530	GGUCACC	CUGADGAGGCCGAAAGGCCGAA	AUCAGC
1530	GGUCACC	CUGADGAGGCCGAAAGGCCGAA	AUCAGC
1563	GGGAGCA	CUGADGAGGCCGAAAGGCCGAA	AGGUUCA
1563	GGGAGCA	CUGADGAGGCCGAAAGGCCGAA	AGGUUCA
1568	CGUGGGG	CUGADGAGGCCGAAAGGCCGAA	AGCAGAG
1589	GGGCAAU	CUGADGAGGCCGAAAGGCCGAA	ACAGUCA
1592	GUAGGGC	CUGADGAGGCCGAAAGGCCGAA	AUUAACG
1617	CGAUUUU	CUGADGAGGCCGAAAGGCCGAA	AUUUCUC
1623	UUUAAGC	CUGADGAGGCCGAAAGGCCGAA	AUUUUA
1633	GGUUUUU	CUGADGAGGCCGAAAGGCCGAA	AUUUUA

Table 27: Human TNP- $\alpha$  Hairpin Ribozyme Sequences

nt. Position	Hairpin Ribozyme Sequence	Substrate
46	AGCCUGG AGAA GUUUGU ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	ACUACU GAC CCACGCU
54	GAGGUGG AGAA GUUGGU ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	ACCCACG GCU CCACCCUC
185	GGAGAGA AGAA GAGGAA ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	UUCCUCA GGC UCUUUCUC
201	CUCCACG AGAA GAGAG ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	CUUUCU GAU CGUGGCG
230	GUCCAGCA AGAA GAAAG ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	CUCUUCU GGC UCUUGCAC
234	CAAGUCC AGAA GGCAGA ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	UCUGCCU GCU GACACUUG
254	CTUCUGG AGAA GAUCAC ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	GUGAUCG GGC CCGAGAG
296	GCCAGAG AGAA GAUUG ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	CUAAUCA GGC CUCUGGCC
317	AGAAAGU AGAA GAUUG ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	GCAGUCA GAU CAUCUUCU
387	GCACUAG AGAA GACUCC ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	AGGGGCA GCU CAGUGGCC
404	AUUGCCC AGAA GUUCAG ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	CUAAACC GGC GGGCCAAU
453	GCACACC AGAA GGUUUA ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	AUAAACA GCU GUGUGGCC
518	GGUGGAG AGAA GCUUUG ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	CAAGGCU GGC CUCUCCAC
554	GGCAUCC AGAA GAUUG ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	ACCAUCA GGC GCAUCCGC
576	UGUAGGA AGAA GCGAUG ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	CAUCGCC GUC UCUUACCA
607	UACCTUG AGAA GTUUG ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	UCUUGCA GCU GAGGAGG
704	AGCCUGA AGAA GUCACC ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	GGUGACC GAC UCAAGGCU
726	GAUAGUG AGAA GAUUGA ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	UCAAUCG GGC CGACUAUC
730	GGCAUUG AGAA GGGGAG ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	UCGGCCC GAC UAUUCUGA
824	GGGAUUA AGAA GGGGAG ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	CUCCCCU GGC CCAUUCGC
1042	GGGAUCA AGAA GUAGGC ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	GCUACA GCU UUGAUCCC
1168	CUAGAAAC AGAA GGAAG ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	CUCUCCA GAU GUUCCAG
1178	UCAAAGAA AGAA GGAAC ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	GUUUGCA GAC UUCUUGA
1202	AUGGGAG AGAA GGGCUC ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	GAGCCCA GGC CUCCCAU
1220	AUAGAGG AGAA GGUUCC ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	GGAGCCA GCU CUCUCUUA
1284	AUACUUC AGAA GUAAAU ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	AUUACA GAU GAUUGUAU
1340	UGAGCCA AGAA GCUUCU ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	AGGAGCU GGC UUGGCCUA
1390	UACAUGG AGAA GCUUUA ACCAGAGAAACACACGUGUGGUAUUAUCCUGGUA	AUAGGCU GUU CCAUGUA

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1452	ACAACTUA	AGAA	GAUAAU	ACCAGAGAAACACACACGUGUGUGUACAUAUACCTUGGUA	AUUUUCU	GAU	UAAAGUUGU
1475	GUCAACCA	AGAA	GCAUUG	ACCAGAGAAACACACACGUGUGUGUACAUAUACCTUGGUA	CAAUUCU	GAU	UUGGUGAC
1513	CCUUGGGG	AGAA	GAGGCC	ACCAGAGAAACACACACGUGUGUGUACAUAUACCTUGGUA	GGCCUCU	GCU	CCCCAGGG
1541	GAUUGUA	AGAA	GAUUNC	ACCAGAGAAACACACACGUGUGUGUACAUAUACCTUGGUA	GUAAUUG	GCC	UACUAUUC

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Table 28: Mouse TNF- $\alpha$  Hairpin Ribozyme Sequences

nt. Position	Hairpin Ribozyme Sequence	Substrate
103	GUGAAGG AGA GAACTU ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	AGGUUU GUC CCUUUAC
256	UGGAGAG AGA GAGCA ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	UGUUA GGC UUUUUA
272	CUCCACA AGA GAAUG ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	CAUUUU GCU UGUGGAG
301	GUUAGUA AGA GAAAG ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	CUUUUU GUC UAGUGAC
325	CCUUUGG AGA GUAUC ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	GUUAUG GUC CCUAAAG
370	GGCCUAG AGA GUAUG ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	GUUAUA GCU CUUUUCC
383	GUUGAGG AGA GUUUG ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	UGGUCA GAC CUUUAAC
397	AGAGAGG AGA GAGUU ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	ACAUUA GAU CAUUUUU
467	GCACUCC AGA GUUUU ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	UGGUCA GAC CUUUAAC
546	UACCAUC AGA GGUUU ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	AGGACA GCU GAGGUCC
549	UACCAUC AGA GGUUU ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	GGGUCA GUC GAGGUCC
598	GUUGUUG AGA GUUUU ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	CAAGUU GUC GAGGUCC
603	AGCAAGU AGA GUUUU ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	CUUUUU GAC UAGGUUU
631	AGCAAGU AGA GUUUU ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	ACGUUA GUC GAGGUUU
634	GUUAGCA AGA GUUUU ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	GUUAUG GCU UUUUUU
675	CUUUUUG AGA GUUUU ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	CUUUUU GUC GAGGUUU
691	GUUUUUG AGA GUUUU ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	AGUUUU GUC GAGGUUU
764	AGUAGU AGA GUUUU ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	UUUUUA GCU GAGGUUU
803	AGUAGU AGA GUUUU ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	CUUUUU GUC GAGGUUU
895	AGUAGU AGA GUUUU ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	CUUUUU GUC GAGGUUU
906	AGUAGU AGA GUUUU ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	CUUUUU GUC GAGGUUU
920	AGUAGU AGA GUUUU ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	CUUUUU GUC GAGGUUU
953	AGUAGU AGA GUUUU ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	CUUUUU GUC GAGGUUU
1175	AGUAGU AGA GUUUU ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	CUUUUU GUC GAGGUUU
1220	AGUAGU AGA GUUUU ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	CUUUUU GUC GAGGUUU
1230	AGUAGU AGA GUUUU ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	CUUUUU GUC GAGGUUU
1256	AGUAGU AGA GUUUU ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	CUUUUU GUC GAGGUUU
1274	AGUAGU AGA GUUUU ACCGAGAAACACACGUGUGUGUACUUAUACUUGUA	CUUUUU GUC GAGGUUU

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Table 29: Human bcr/abl HH Target Sequence

Sequence ID No.	HH Target Sequence
<u>b2-a2</u> <u>Junction</u>	
20	UGACCAUCA AUA AGGAAGAAGOC
21	GAAGAAGOC CUU CAGGGGOCAGU
22	AAGAAGOC UUC AGGGGOCAGUA
<u>b3-a2</u> <u>Junction</u>	
23	UAAGCAGAG UUC AAAAGGOCUUC
24	UCAAAGOC CUU CAGGGGOCAGU
25	CAAAAGOC UUC AGGGGOCAGUA

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Table 30: Human *bcr-abl* HH Ribozyme Sequences

Sequence ID No.	HH Ribozyme Sequence
26	GCCUUCUUCU CUGAUGAGGCCGAAAGGCCGAA AUGAUGGUA
27	ACUGGCGCGUG CUGAUGAGGCCGAAAGGCCGAA AGGCCUUCUC
28	UACUGGCGCGU CUGAUGAGGCCGAAAGGCCGAA AAGGCUUCU
29	GAAGGCUUUU CUGAUGAGGCCGAAAGGCCGAA AACUCUGCUA
30	ACUGGCGCGUG CUGAUGAGGCCGAAAGGCCGAA AGGCCUUUGA
31	UACUGGCGCGU CUGAUGAGGCCGAAAGGCCGAA AAGGCUUUUG

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Table 31: RSV (1B) HH Target Sequence

nt. Position	HH Target Sequence	nt. Position	HH Target Sequence
10	GGCAAAU A AADCAAU	276	AAAAUAAU A CUGAADA
14	AAUAAAU C AADUCAG	283	ACUGAAU A CAACACA
18	AAUCAAU U CAGCCAA	295	ACAAAAU A UGGCAU
19	ADCAAAU C AGCCAAC	303	UGGCACU U UCCCUAU
54	CAUGAU A AUAACAC	304	GGCACU U CCGUADG
57	UGAUAU A CACCACA	305	GCACUU C CCGADGC
77	UGAUGAU C ACAGACA	309	UUUCCCU A UGOCAAU
94	AGACCGU U GUCACUU	317	UGCCAAU A UUCAUCA
97	CCGUUGU C ACUUGAG	319	CCAAUAU U CAUCAAU
101	UGUCACU U GAGACCA	320	CAUAUU C AUCAUUC
110	AGACCAU A AUAACAU	323	UAUOCAU C AADCAUG
113	CCAAUAU A ACAUCAC	327	CAUCAAU C AUGAUGG
118	AUAACAU C ACUAACC	337	GAUGGGU U CUUAGAA
122	CAUCACU A ACCAGAG	338	AUGGGUU C UUAAGAU
134	GAGACAU C AUAACAC	340	GGGUUCU U AGAUGC
137	ACAUCAU A ACACACA	341	GGUUCUU A GAUUGCA
148	CACAAAU U UAUAUAC	350	AAGGCAU U GSCAUUA
149	ACAAAUU U AUAUAU	356	UGGCAU U AAGCCTA
150	CAAAUUU A UAUAUU	357	UGGCAU A AGCCTAC
152	AAUUUAU A UACUUGA	363	UAAGCCU A CAAAGCA
154	UUUAUAU A CUUGADA	372	AAAGCAU A CCCCCAU
157	AUAUAU U GAUAAAU	375	GCAUAU C CCAUAU
161	ACUUGAU A AADCAUG	380	CCCCAU A AUAUACA
165	GAUAAAU C AUGAADG	383	CCAUAU A UACAAGU
176	AADGCAU A GUGAGAA	385	AUAUAU A CAAGUAU
188	GAUAACU U GAUGAAA	391	UACAAGU A UGAUCCU
208	GGCACAU U UACAUCU	396	GUUUGAU C UCAAUCC
209	CCACAUU U ACAUCCU	398	AUGAUU C AADCCAU
210	CACAUUU A CAUUCUU	402	UCUCAU C CAUAAAU
214	UUUACAU U CCGGUC	406	AAUCCAU A AAUUUCA
215	UUACAUU C CUGGUA	410	CAUAAAU U UCAACAC
221	UCCUGGU C AAGUAUG	411	AUAUAU U CAACACA
226	GUCAACU A UGAUADG	412	UAUAUUU C AACACAA
239	UGAAACU A UUAACAA	421	ACACAAU A UUCACAC
241	AAACUAU U ACACAAA	423	ACAAUAU U CACACAA
242	AACUAUU A CACAAAG	424	CAUAUAU C ACACAAU
251	ACAAAGU A GGAAGCA	432	ACACAAU C UAAAACA
261	AAGCAU A AAUAUA	434	ACAUAU A AAACAAC
265	ACTAAAU A UAAAAA	446	AACACU C UAUGCAU
267	UAAUAU A AAAAAA	448	CAACUU A UGCAUAA
274	AAAAAAU A UACUGAA	454	UAUGCAU A ACUAUAC

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458	CAUACU A UACUCCA
460	UAACU A CUCCAA
463	CUADACU C CAUAGUC
467	ACUCCAU A GUCCAGA
470	CCAUAGU C CAGADGG
489	UGAAAAU U AUAAGUA
490	GAAAAU A UAGUAAU
492	AAAUU A GUAAUU
495	UUAUAGU A AUUAAA

Table 32: RSV (1B) HH Ribozyme Sequence

nt. Position	HH Ribozyme Sequence
10	AUUGAUU CUGAUGAGGCCGAAAGGCCGAA AUUUGGC
14	COGAADU CUGAUGAGGCCGAAAGGCCGAA AUUUAUU
18	UUGGCGG CUGAUGAGGCCGAAAGGCCGAA AUUGAUU
19	GUUGGCU CUGAUGAGGCCGAAAGGCCGAA AAUUGAU
54	GGUGUAU CUGAUGAGGCCGAAAGGCCGAA AGCAUUG
57	UGGGGUG CUGAUGAGGCCGAAAGGCCGAA AUUAUCA
77	UGUCUGU CUGAUGAGGCCGAAAGGCCGAA AUCAUCA
94	AAGUGAC CUGAUGAGGCCGAAAGGCCGAA ACCGUCU
97	CUCAAGU CUGAUGAGGCCGAAAGGCCGAA ACAACGG
101	UGGUCUC CUGAUGAGGCCGAAAGGCCGAA AGUGACA
110	AUGUUUU CUGAUGAGGCCGAAAGGCCGAA AUGSUUU
113	GUGAUGU CUGAUGAGGCCGAAAGGCCGAA AUUAUGG
118	GGUUAUU CUGAUGAGGCCGAAAGGCCGAA AUGUUUU
122	CUCUGGU CUGAUGAGGCCGAAAGGCCGAA AGUGAUG
134	GUGUUUU CUGAUGAGGCCGAAAGGCCGAA AUGUCUC
137	UGGUGGU CUGAUGAGGCCGAAAGGCCGAA AUGAUGU
148	GUUAUUA CUGAUGAGGCCGAAAGGCCGAA AUUUGUG
149	AGUAUUU CUGAUGAGGCCGAAAGGCCGAA AAUUUGU
150	AAGUUAU CUGAUGAGGCCGAAAGGCCGAA AAUUUUG
152	UCAAGUA CUGAUGAGGCCGAAAGGCCGAA AUAAAUU
154	UAUCAAG CUGAUGAGGCCGAAAGGCCGAA AUUAUAA
157	AUUUAUC CUGAUGAGGCCGAAAGGCCGAA AGUAUUU
161	CAUGAUU CUGAUGAGGCCGAAAGGCCGAA AUCAAGU
165	CAUUCAU CUGAUGAGGCCGAAAGGCCGAA AUUAUUC
176	UUCUCAC CUGAUGAGGCCGAAAGGCCGAA AUGCAUU
188	UUUCAUC CUGAUGAGGCCGAAAGGCCGAA AGUUUUC
208	GAAUGUA CUGAUGAGGCCGAAAGGCCGAA AUGUGGC
209	GGAAUGU CUGAUGAGGCCGAAAGGCCGAA AAUGUGG
210	AGGAADG CUGAUGAGGCCGAAAGGCCGAA AAADUGG
214	GACCAGG CUGAUGAGGCCGAAAGGCCGAA AUGUAAA
215	UGACCAG CUGAUGAGGCCGAAAGGCCGAA AADGUAA
221	CAUAGUU CUGAUGAGGCCGAAAGGCCGAA ACCAGGA
226	CAUUUCA CUGAUGAGGCCGAAAGGCCGAA AGUUGAC
239	UGUGUAA CUGAUGAGGCCGAAAGGCCGAA AGUUUCA
241	UUUGUGU CUGAUGAGGCCGAAAGGCCGAA AUAGUUU
242	CUUUGUG CUGAUGAGGCCGAAAGGCCGAA AAUAGUU
251	UGCUUCC CUGAUGAGGCCGAAAGGCCGAA ACUUUGU
261	UUUAUUU CUGAUGAGGCCGAAAGGCCGAA AGUGCUU
265	UUUUUUA CUGAUGAGGCCGAAAGGCCGAA AUUUAGU
267	UAUUUUU CUGAUGAGGCCGAAAGGCCGAA AUUAUUU
274	UUCAGUA CUGAUGAGGCCGAAAGGCCGAA AUUUUUU
276	UAUUCAG CUGAUGAGGCCGAAAGGCCGAA AUUAUUU

283	UGUGUUG	CUGAUGAGGCGAAAGGCCGAA	AUUCAGU
295	AGUGCCA	CUGAUGAGGCGAAAGGCCGAA	AUUUUGU
303	AUAGGGA	CUGAUGAGGCGAAAGGCCGAA	AGUGCCA
304	CAUAGGG	CUGAUGAGGCGAAAGGCCGAA	AAGUGCC
305	GCAUAGG	CUGAUGAGGCGAAAGGCCGAA	AAAGUGC
309	ADUGGCA	CUGAUGAGGCGAAAGGCCGAA	AGGGAUA
317	UGAUGAA	CUGAUGAGGCGAAAGGCCGAA	AUUGGCA
319	AUUGAUG	CUGAUGAGGCGAAAGGCCGAA	AUAUGGG
320	GADUGAU	CUGAUGAGGCGAAAGGCCGAA	AAUAUUG
323	CAUGAUU	CUGAUGAGGCGAAAGGCCGAA	AUGAUAU
327	CCAUCAU	CUGAUGAGGCGAAAGGCCGAA	AUUGAUG
337	UUCUAAG	CUGAUGAGGCGAAAGGCCGAA	ACCCAUU
338	AUUCUAA	CUGAUGAGGCGAAAGGCCGAA	AAUCCAU
340	GCAUUCU	CUGAUGAGGCGAAAGGCCGAA	AGAAUCC
341	UGCAUUC	CUGAUGAGGCGAAAGGCCGAA	AAAGAAC
350	UAUUGCC	CUGAUGAGGCGAAAGGCCGAA	AUGCAUU
356	UAGGCUU	CUGAUGAGGCGAAAGGCCGAA	AUGCCAA
357	GUAGGCU	CUGAUGAGGCGAAAGGCCGAA	AADGCCA
363	UGCUUUG	CUGAUGAGGCGAAAGGCCGAA	AGGCCUA
372	AUGGGAG	CUGAUGAGGCGAAAGGCCGAA	AUGCUUU
375	AUUUUGG	CUGAUGAGGCGAAAGGCCGAA	AGUAUUG
380	UGUAUAU	CUGAUGAGGCGAAAGGCCGAA	AUGGGAG
383	ACUUGUA	CUGAUGAGGCGAAAGGCCGAA	AUAUUGG
385	AUAUUUG	CUGAUGAGGCGAAAGGCCGAA	AUAUAUU
391	GAGAUCA	CUGAUGAGGCGAAAGGCCGAA	ACUUGUA
396	GGAUUGA	CUGAUGAGGCGAAAGGCCGAA	AUUAUAC
398	AUGGAUU	CUGAUGAGGCGAAAGGCCGAA	AGAUCAU
402	AUUUAUG	CUGAUGAGGCGAAAGGCCGAA	AUUGAGA
406	UGAAAUU	CUGAUGAGGCGAAAGGCCGAA	AUGGAUU
410	GUGUUGA	CUGAUGAGGCGAAAGGCCGAA	AUUUAUG
411	UGUGUUG	CUGAUGAGGCGAAAGGCCGAA	AADUUAU
412	UUGUGUU	CUGAUGAGGCGAAAGGCCGAA	AAAUUAU
421	GUGUGAA	CUGAUGAGGCGAAAGGCCGAA	AUUGUGU
423	UUGUGUG	CUGAUGAGGCGAAAGGCCGAA	AUAUUGU
424	AUUGUGU	CUGAUGAGGCGAAAGGCCGAA	AUAUUGG
432	UGUUUUA	CUGAUGAGGCGAAAGGCCGAA	AUUGUGU
434	GUUGUUU	CUGAUGAGGCGAAAGGCCGAA	AGAUUGU
446	AUGCAUA	CUGAUGAGGCGAAAGGCCGAA	AGUUGUU
448	UUAUGCA	CUGAUGAGGCGAAAGGCCGAA	AGAGUUG
454	GUUAUAG	CUGAUGAGGCGAAAGGCCGAA	AUGCAUA
458	UGGAGUA	CUGAUGAGGCGAAAGGCCGAA	AGUUAUG
460	UAUGGAG	CUGAUGAGGCGAAAGGCCGAA	AUAUUUA
463	GACUAUG	CUGAUGAGGCGAAAGGCCGAA	AGUAUAG
467	UCUGGAC	CUGAUGAGGCGAAAGGCCGAA	AUGGAGU
470	CCAUCUG	CUGAUGAGGCGAAAGGCCGAA	ACUAUUG
489	UUAUAUU	CUGAUGAGGCGAAAGGCCGAA	AUUUUAU
490	AUAUAUA	CUGAUGAGGCGAAAGGCCGAA	AAUUUUA
492	AAAUUAU	CUGAUGAGGCGAAAGGCCGAA	AUAUUUU
495	UUUAAAU	CUGAUGAGGCGAAAGGCCGAA	ACUAUUA

Table 33 : RSV (1C) HH target Sequence

nt. Position	Target Sequence	nt. Position	Target Sequence
10	GGCAAAU A AGAUAUU	165	UACAUUU A ACUAACG
16	UAAGAAU U UGAUAAG	169	UUUAACU A ACGCUUU
17	AAGAAUU U GAUAAGU	175	UAAGGCU U UGGCUAA
21	AUUUGAU A AGUACCA	176	AACGCUU U GGUUAAG
25	GAUAAGU A CCACUA	181	UUUGGCU A AGGCAGU
31	UACCAU U AAAUUUA	192	CAGUGAU A CAUACAA
32	ACCACUU A AAUUUAA	196	GAUACAU A CAADCAA
36	CUUAAAU U UAACUCC	201	AUACAAU C AAADUGA
37	UUAAAUU U AACUCCC	206	AUCAAAU U GAADGGC
38	UAAAUUU A ACUCCCU	216	AUGGCAU U GUGGUUG
42	UUUAACU C CCUUGGU	221	AUUUGUU U UGUUGCAU
46	ACUCCCU U GGUUAGA	222	UUGUGUU U GUGCAUG
50	CCUUGGU U AGAGADG	231	UGCAUGU U AUUACAA
51	CUUGGUU A GAGADGG	232	GCAUGUU A UUAACAAG
67	CAGCAAU U CAUOGAG	234	AUGUUAU U ACAAGUA
68	AGCAAUU C AUUGAGU	235	UGUUAUU A CAAGUAG
71	AAUUCAU U GAGUADG	241	UACAAGU A GUGAUUAU
76	AUUGAGU A UGAUAAA	247	UAGUGAU A UUGGCCC
81	GUADGAU A AAAGUUA	249	GGGAUAU U UGCCCUA
87	UAAAAGU U AGAUUAC	250	UGADAUU U GCCCUAA
88	AAAAGUU A GAUACA	256	UUGCCCU A AUAAUAA
92	GUUAGAU U ACAAAAU	259	CCCUAAU A AUAAUAU
93	UUAGAUU A CAAAAUU	262	UAUAUAU A AUADUGU
100	ACAAAAU U UGUUGA	265	UAUAUAU A UUGUAGU
101	CAAAAAU U GUUUGAC	267	AUAUAUAU U GUAGUAA
104	AAUUUGU U UGACAAU	270	AUAUUGU A GUAAAAU
105	AUUUGUU U GACAADG	273	UUGUAGU A AAADCCA
120	AUGAAGU A GCAUUGU	278	GUAAAAU C CAADUUC
125	GUAGCAU U GUUAAA	283	AUCCAAD U UCACAAC
128	GCAUUGU U AAAAAUA	284	UCCAADU U CACAACA
129	CAUUGUU A AAAAUAA	285	CCAAUUU C ACAACAA
135	UAAAAAU A ACADGCU	300	UGOCAGU A CUACAAA
143	ACAUGCU A UACUGAU	303	CAGUACU A CAAAAUG
145	AUGCUAU A CUGAUAA	316	UGGAGGU U AUADUAG
151	UACUGAU A AAUUAUU	317	GGAGGUU A UAADUGG
155	GAUAAAU U AAUACAU	319	AGGUUAU A UAUGGGA
156	AUAAAUU A AUACAUU	321	GUUAUAU A UGGGAAA
159	AAUUAUU A CAUUUAA	338	AUGGAUU U AACACAU
163	AAUACAU U UAACUAA	339	UGGAUUU A ACACAUU
164	AUACAUU U AACUAAC	346	AACACAU U GCUUCA

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350 CAUUGCU C UCAACCU  
352 UUGCUU C AACCUAA  
358 UCAACCU A AUGGUCU  
364 UAUUGU C UACUAGA  
366 AUGGUCU A CUAGAUG  
369 GUCUACU A GAUGACA  
379 UGACAAU U GUGAAAU  
387 GUGAAAU U AAUUCU  
388 UGAAAUU A AAUUCUC  
392 AUUAAAU U CUCCAAA  
393 UUAUUU C UCCAAA  
395 AAUUCU C CAAAAA  
405 AAAAACU A AGUGAUU  
412 AAGUGAU U CAACAAU  
413 AGUGAUU C AACRAUG  
427 GACCAAU U AUUAGAA  
428 ACCAAAU A UAUGAU  
430 CAUUUAU A UGAUUA  
436 UAUGAU C AAUUAUC  
440 AAUUAU U AUUUGAA  
441 AUCAAU A UCUGAAU  
443 CAUUUAU C UGAUUUA  
449 UCUGAAU U ACUUGGA  
450 CUGAAU A CUUGGAU  
453 AAUUAU U GUAUUG  
458 CUUGGAU U UGADUU  
459 UUGGAU U GAUUUA  
463 AUUUGAU C UUAUUC  
465 UUGAUU U AAUCCAU  
466 UGAUUCU A AUUUAU  
469 UCUUAU C CAUAAAU  
473 AAUCCAU A AAUUAU  
477 CAUAAAU U AUUAUA  
478 AUAAAU A UAUAUA  
480 AAUUAU A AUUAUA  
483 UUAUAU U AAUAUA  
484 UAUAUA A AUUAUA  
487 AAUUAU A UCAUAU  
489 UUAUAU C AAUAUA  
494 AUUAUA A GCAUAU  
501 AGCAAU C AAUGUA  
507 UCRAUGU C ACUAUA  
511 UGUCAU A ACAUAU  
519 ACACCAU U AGUUAU  
520 CACCAU A GUUAUA  
523 CAUUAU U AAUAUA  
524 AUUAUA A AUUAUA

Table 34: RSV (1C) HH Ribozyme Sequence

nt. Position	HH Ribozyme Sequence
10	AAAUUCU CUGAUGAGGCGGAAAGGCCGAA AUUGGC
16	CUUADCA CUGAUGAGGCGGAAAGGCCGAA AUUCUCA
17	ACUUAUC CUGAUGAGGCGGAAAGGCCGAA AAUUCUU
21	UGGUACU CUGAUGAGGCGGAAAGGCCGAA AUCAAAD
25	UAAGUGG CUGAUGAGGCGGAAAGGCCGAA ACUUAUC
31	UAAAUUU CUGAUGAGGCGGAAAGGCCGAA AGUGGUA
32	UUAAAUU CUGAUGAGGCGGAAAGGCCGAA AAGUGGU
36	GGAGUUA CUGAUGAGGCGGAAAGGCCGAA AUUUAAG
37	GGGAGUU CUGAUGAGGCGGAAAGGCCGAA AAUUAUA
38	AGGGAGU CUGAUGAGGCGGAAAGGCCGAA AAADUUA
42	ACCAAGG CUGAUGAGGCGGAAAGGCCGAA AGUUAUA
46	UCUAACC CUGAUGAGGCGGAAAGGCCGAA AGGGAGU
50	CADUCUU CUGAUGAGGCGGAAAGGCCGAA ACCAAGG
51	CCADUCU CUGAUGAGGCGGAAAGGCCGAA AACCAAG
67	CUCAUUG CUGAUGAGGCGGAAAGGCCGAA AUUGGUG
68	ACUCAAU CUGAUGAGGCGGAAAGGCCGAA AAUGGCU
71	CAUAUCU CUGAUGAGGCGGAAAGGCCGAA AUGAAUU
76	UUUAUCA CUGAUGAGGCGGAAAGGCCGAA ACUCAAU
81	UAACUUU CUGAUGAGGCGGAAAGGCCGAA AUCAUAC
87	GUAAUCU CUGAUGAGGCGGAAAGGCCGAA ACUUUUA
88	UGUAUUC CUGAUGAGGCGGAAAGGCCGAA AACUUUU
92	AUUUUUG CUGAUGAGGCGGAAAGGCCGAA AUCAUAC
93	AAUUUUG CUGAUGAGGCGGAAAGGCCGAA AAUCUUA
100	UCAAAAC CUGAUGAGGCGGAAAGGCCGAA AUUUUGU
101	GUCAAAC CUGAUGAGGCGGAAAGGCCGAA AAUUUUG
104	AUUGCCA CUGAUGAGGCGGAAAGGCCGAA ACUAAAU
105	CADUGUC CUGAUGAGGCGGAAAGGCCGAA AACAAAU
120	ACAADGC CUGAUGAGGCGGAAAGGCCGAA ACUUCAU
125	UUUUAAC CUGAUGAGGCGGAAAGGCCGAA AUGCUAC
128	UAUUUUU CUGAUGAGGCGGAAAGGCCGAA ACUADGC
129	UUUUUUU CUGAUGAGGCGGAAAGGCCGAA AACAAUG
135	AGCAUGU CUGAUGAGGCGGAAAGGCCGAA AUUUUUA
143	AUCAGUA CUGAUGAGGCGGAAAGGCCGAA AGCADGU
145	UUUUCAG CUGAUGAGGCGGAAAGGCCGAA AUUAGAU
151	AUUAAUU CUGAUGAGGCGGAAAGGCCGAA AUCAGUA
155	AUGUAUU CUGAUGAGGCGGAAAGGCCGAA AUUUUUC
156	AADGUUU CUGAUGAGGCGGAAAGGCCGAA AAUUUAU
159	UUAAAUU CUGAUGAGGCGGAAAGGCCGAA AUUAUUU
153	UUAGUUA CUGAUGAGGCGGAAAGGCCGAA AUGUAUU
154	GUUAGUU CUGAUGAGGCGGAAAGGCCGAA AADGUUU
155	CGUUAUU CUGAUGAGGCGGAAAGGCCGAA AAUUGUA

169	AAAGGCU	CUGAUGAGGCGGAAAGGCCGAA	AGUUAAA
175	UUAGCCA	CUGAUGAGGCGGAAAGGCCGAA	AGCGUUA
176	CUUAGCC	CUGAUGAGGCGGAAAGGCCGAA	AAGCGUU
181	ACUGGCU	CUGAUGAGGCGGAAAGGCCGAA	AGCCAAA
192	UUGUAUG	CUGAUGAGGCGGAAAGGCCGAA	AUCACUG
196	UUGAUUG	CUGAUGAGGCGGAAAGGCCGAA	AUGUATC
201	UCAAUUU	CUGAUGAGGCGGAAAGGCCGAA	AUUGUAU
206	GCCAUUC	CUGAUGAGGCGGAAAGGCCGAA	AUUUGAU
216	CAAAAC	CUGAUGAGGCGGAAAGGCCGAA	AUGCCAU
221	AUGCACA	CUGAUGAGGCGGAAAGGCCGAA	ACACAAU
222	CAUGCAC	CUGAUGAGGCGGAAAGGCCGAA	AACACAA
231	UUGUAAU	CUGAUGAGGCGGAAAGGCCGAA	ACAUGCA
232	CUUGUAA	CUGAUGAGGCGGAAAGGCCGAA	AACAUCC
234	UACUUGU	CUGAUGAGGCGGAAAGGCCGAA	AUAACAU
235	CUACUUG	CUGAUGAGGCGGAAAGGCCGAA	AUAUACA
241	AUAUCAC	CUGAUGAGGCGGAAAGGCCGAA	ACUUGUA
247	GGGCAAA	CUGAUGAGGCGGAAAGGCCGAA	AUCACUA
249	UAGGGCA	CUGAUGAGGCGGAAAGGCCGAA	AUAUCAC
250	UUAGGGC	CUGAUGAGGCGGAAAGGCCGAA	AUAUACA
256	UUAUUAU	CUGAUGAGGCGGAAAGGCCGAA	AGGGCAA
259	AUAUUAU	CUGAUGAGGCGGAAAGGCCGAA	AUUAGGG
262	ACAAUAU	CUGAUGAGGCGGAAAGGCCGAA	AUUUAUA
265	ACTACAA	CUGAUGAGGCGGAAAGGCCGAA	AUUUAUA
267	UUACUAC	CUGAUGAGGCGGAAAGGCCGAA	AUAUUAU
270	AUUUUAC	CUGAUGAGGCGGAAAGGCCGAA	ACAAUAU
273	UGGAUUU	CUGAUGAGGCGGAAAGGCCGAA	ACUACAA
278	GAAAUUG	CUGAUGAGGCGGAAAGGCCGAA	AUUUUAC
283	GUUGUGA	CUGAUGAGGCGGAAAGGCCGAA	AUUGGAU
284	UGUUGUG	CUGAUGAGGCGGAAAGGCCGAA	AADUGGA
285	UUGUUGU	CUGAUGAGGCGGAAAGGCCGAA	AAAUUGG
300	UUUGUAG	CUGAUGAGGCGGAAAGGCCGAA	ACUGGCA
303	CAUUUUG	CUGAUGAGGCGGAAAGGCCGAA	AGUAUUG
316	CADUAUA	CUGAUGAGGCGGAAAGGCCGAA	ACCUCCA
317	CCADUAU	CUGAUGAGGCGGAAAGGCCGAA	AACCUCC
319	UCCAUUA	CUGAUGAGGCGGAAAGGCCGAA	AUAACCU
321	UUUCCCA	CUGAUGAGGCGGAAAGGCCGAA	AUAUAAC
338	AUGGUGU	CUGAUGAGGCGGAAAGGCCGAA	AUUCCAU
339	AAGGUGU	CUGAUGAGGCGGAAAGGCCGAA	AADUCCA
346	UGAGAGC	CUGAUGAGGCGGAAAGGCCGAA	AUGUGUU
350	AGGUUGA	CUGAUGAGGCGGAAAGGCCGAA	AGCAAUG
352	UUAGGUU	CUGAUGAGGCGGAAAGGCCGAA	AGAGCAA
358	AGACCAU	CUGAUGAGGCGGAAAGGCCGAA	AGGUUGA
364	UCUAGUA	CUGAUGAGGCGGAAAGGCCGAA	ACCAUUA
366	CAUCUAG	CUGAUGAGGCGGAAAGGCCGAA	AGACCAU
369	UGUCAUC	CUGAUGAGGCGGAAAGGCCGAA	AGUAGAC
379	AUUUCAC	CUGAUGAGGCGGAAAGGCCGAA	AUUGUCA
387	AGAAUUU	CUGAUGAGGCGGAAAGGCCGAA	AUUUCAC
388	GAGAAUU	CUGAUGAGGCGGAAAGGCCGAA	AUUUCCA
392	UUUGGAG	CUGAUGAGGCGGAAAGGCCGAA	AUUUAAU



393	UUUUGGA	CUGAUGAGGCGGAAAGGCGGAA	AAUUUAA
395	UUUUUUG	CUGAUGAGGCGGAAAGGCGGAA	AGAAUUU
405	AAUCACU	CUGAUGAGGCGGAAAGGCGGAA	AGUUUUU
412	AUUGUUG	CUGAUGAGGCGGAAAGGCGGAA	AUCACUU
413	CAUUGUU	CUGAUGAGGCGGAAAGGCGGAA	AAUCACU
427	UUCAUAU	CUGAUGAGGCGGAAAGGCGGAA	AUUGGUC
428	AUUCAUU	CUGAUGAGGCGGAAAGGCGGAA	AAUUGGU
430	UGAUUCA	CUGAUGAGGCGGAAAGGCGGAA	AUAADUG
436	GAAUAUU	CUGAUGAGGCGGAAAGGCGGAA	AUUCAUU
440	UUCAGAU	CUGAUGAGGCGGAAAGGCGGAA	AUUGAUU
441	AUUCAGA	CUGAUGAGGCGGAAAGGCGGAA	AAUUGAU
443	UAADUCA	CUGAUGAGGCGGAAAGGCGGAA	AUAADUG
449	UCCAGAU	CUGAUGAGGCGGAAAGGCGGAA	AUUCAGA
450	AUCCAAG	CUGAUGAGGCGGAAAGGCGGAA	AAUCCAG
453	CAAAUCC	CUGAUGAGGCGGAAAGGCGGAA	AGUAAUU
458	AAGAUCA	CUGAUGAGGCGGAAAGGCGGAA	AUCCAAG
459	UAGAUUC	CUGAUGAGGCGGAAAGGCGGAA	AAUCCAA
463	GGAUUAA	CUGAUGAGGCGGAAAGGCGGAA	AUCAAUU
465	AUGGAUU	CUGAUGAGGCGGAAAGGCGGAA	AGAUCAA
466	UADGGAU	CUGAUGAGGCGGAAAGGCGGAA	AAGAUCA
469	AUUUAUG	CUGAUGAGGCGGAAAGGCGGAA	AUUUAGA
473	UAUAUUU	CUGAUGAGGCGGAAAGGCGGAA	AUGGAUU
477	UAADUAA	CUGAUGAGGCGGAAAGGCGGAA	AUUUAUG
478	UUUAUUU	CUGAUGAGGCGGAAAGGCGGAA	AAUUUUU
480	UAUUAAU	CUGAUGAGGCGGAAAGGCGGAA	AUAUUUU
483	UGAUUAU	CUGAUGAGGCGGAAAGGCGGAA	AUUUAUA
484	UUGAUUU	CUGAUGAGGCGGAAAGGCGGAA	AAUUAUA
487	UAGUUGA	CUGAUGAGGCGGAAAGGCGGAA	AUUUAUU
489	GUUAGUU	CUGAUGAGGCGGAAAGGCGGAA	AUAUUAA
494	GAUUUUG	CUGAUGAGGCGGAAAGGCGGAA	AGUUGAU
501	UGACAUU	CUGAUGAGGCGGAAAGGCGGAA	AUUUGGU
507	UGUUAGU	CUGAUGAGGCGGAAAGGCGGAA	ACAUUGA
511	AUGGUGU	CUGAUGAGGCGGAAAGGCGGAA	AGUGACA
519	AUUUAUU	CUGAUGAGGCGGAAAGGCGGAA	AUGGUGU
520	UAUUUAC	CUGAUGAGGCGGAAAGGCGGAA	AAUGGUG
523	UUUAUUU	CUGAUGAGGCGGAAAGGCGGAA	ACUUAUG
524	UUUAUUU	CUGAUGAGGCGGAAAGGCGGAA	AAUUAUU

Table 35: RSV (N) HH Target Sequence

nt. Position	HH Target Sequence	nt. Position	HH Target Sequence
9	GGCAAAU A CAAAGAU	217	GGUADGU U AUAAGCG
21	GAUGGCU C UAGGCAA	218	GUADGUU A UAGGCGA
23	UGGCUU C AGCAAAG	220	AUGUUU A UGGGADG
24	GGCUU A GCAAAGU	229	GGGADGU C UAGGCUA
32	GCAAAGU C AAGUUGA	231	GAUGGUU A GGUUAGG
37	GCAAAGU U GAUAGAU	235	UCUAGGU U AGGAAGA
45	GAADGUU A CACUCAA	236	CUAGGUU A GGAAGAG
50	AUACACU C AACAAAG	254	ACACCAU A AAAAUAC
60	CAAGAU C AACUUCU	260	UAAAAU A CCAAGAG
65	AUCAACU U CUGUCAU	263	AAAUACU C AGAGAGG
66	UCAACU C UGUCAUC	277	GCGGGAU A UCAUGUA
70	CUUCUGU C AUCCAGC	279	GGGAUUA C AUGUAAA
73	CUGUCAU C CAGCAAA	284	AUCAUGU A AAAGCAA
82	AGCAAAU A CACCAUC	299	AUGGAGU A GAUGUAA
89	ACACCAU C CAACGGA	305	UAGAUU A ACAACAC
108	AGGAGAU A GUUUGA	315	AACACAU C GUAAGA
111	AGAUAGU A UUGAUAC	318	ACADCGU C AACACAU
113	AUAGUUA U GAUACUC	326	AAGACAU U AADUGAA
117	UAUUGAU A CUCCUAA	327	AGACAUU A AUGGAAA
120	UGAUACU C CUAAUUA	346	AUGAAAU U UGAAGUG
123	UACUCCU A AUUAUGA	347	UGAAAUU U GAAGUGU
126	UCCUAAU U ADGADGU	355	GAAGUGU U AACAUUG
127	CCUAAU A UGADGUG	356	AAGUGUU A ACAUUGG
146	AACACAU C AAUAAGU	361	UUAACAU U GCGAAGC
150	CAUCAAU A AGUUAUG	370	GCAAGCU U AACAAAU
154	AAUAAGU U ADGUGGC	371	CAAGCUU A ACAACUG
155	AUAAGUU A UGUGGCA	383	CUGAAAU U CAADUCA
166	GSCADGU U AUUAUDC	384	UGAAAUU C AAADCAA
167	GCAUGUU A UUAADCA	389	UUCAAAU C AACAUUG
169	AUGUUAU U AADACA	395	UCAACAU U GAGAUAG
170	UGUUAUU A AUCACAG	401	UUGAGAU A GAUUCUA
173	UAUUAUU C ACAGAAG	406	AUAGAUA C UGAAAA
186	AGAUGCU A AUCAUAA	408	AGAAUCC A GAAAAUC
189	UGCUAAU C AUAAAUU	415	AGAAAAU C CUACAAA
192	UAUUAUU A AAUUCAC	418	AAAUCCU A CAAAAAA
196	CAUAAAU U CACUGGG	431	AAAUCCU A AAAGAAA
197	AUAUAUU C ACUGGGU	449	GAGAGGU A GCUCCAG
205	ACUGGGU U AAUAGGU	453	GGUAGCU C CAGAAUA
206	CUUGGUU A AUAGGUA	460	CCAGAAU A CAGGCAU
209	GGUUAUU A GGUADGU	472	CAUGACU C UCCUGAU
213	AAUAGGU A UGUUAUA	474	UGACUCU C CUGAUUG

480	UCCUGAU U GGGGGAU	696	UUUUGGU A UAGCACA
491	GG AUGAU A AUAUUAU	698	UUGGUU A GCACAAU
494	UGAUAAU A UUAUGUA	706	GCACAAU C UUCUACC
496	AUAUAU U AUGUAUA	708	ACAADCU U CUACCCAG
497	UAUAU A UGUADAG	709	CAADCUU C UACCCAGA
501	AUAUGU A UAGCAGC	711	AUCUUCU A CCAGAGG
503	UAUGAU A GCAGCAU	726	UGGCAGU A GAGUUGA
511	GCAGCAU U AGUAUA	731	GUAGAGU U GAAGGGA
512	CAGCAU A GUAAUA	740	AAGGGAU U UUGGCAG
515	CAUAGU A AUAACUA	741	AGGGAU U UUGCAGG
518	UAGUAU A ACUAUAU	742	GGGAUUU U UGCAGGA
522	AUAACU A AAUUGC	743	GGAUUUU U GCAGGAU
526	ACUAUAU U AGCAGCA	751	GCAGGAU U GUUUAUG
527	CUAAAU A GCAGCAG	754	GGAUUGU U UADGAU
544	GACAGAU C UGGUCUU	755	GADUGUU U AUGAUG
549	AUCUGGU C UACAGC	756	AUUGUUU A UGRADGC
551	CGGUCU U ACAGCCG	766	AAUGCCU A UGGUGCA
552	UGGUCU A CAGCCGU	787	GUGAUGU U ACGGUGG
563	CGUGAU U AGGAGAG	788	UGAUGU A CGGUGGG
564	CGUGAU A GGAGAGC	800	GGGAGU C UUAGCAA
573	GAGAGCU A AUAUGU	802	GGAGUCU U AGCAAAA
576	AGCUAAU A AUGUCCU	803	GAGUCU A GCAAAAU
581	AUAUGU C CUA AAAA	811	GCAAAAU C AGUAAA
584	AUGUCCU A AAAAUG	815	AAUCAGU U AAAAUA
603	GAAAGU U ACAAGG	816	AUCAGU A AAAUAU
604	AAAGCU A CAAAGGC	822	UAAAAU A UUAUGUU
613	AAAGCU U ACUACCC	824	AAAAUAU U AUGUUG
614	AAGGCU A CUACCCA	825	AAUAUAU A UGUUAG
617	GUUAU A CCAAGG	829	AUAUGU U AGGACAU
629	AGGACAU A GCCACA	830	UUAUGU A GGACADG
640	AACAGU U CUADGAA	840	ACADGU A GUGUGCA
641	ACAGCU C UADGAAG	866	AACAAGU U GUUGAGG
643	AGCUUCU A UGAAGUG	869	AAGUGU U GAGGUUU
652	GAAGGU U UGAAAA	875	UUGAGGU U UAUAAU
653	AAGUGU U GAAAAAC	876	UGAGGUU U AUGAAUA
663	AAAACAU C CCACUU	877	GAGGUUU A UGAUAU
670	CCCEACU U UAUAAGU	883	UAUGAU A UGCCCCA
671	CCACUU U AUAAGUG	895	CAAAAAU U GGGUGGU
672	CCACUU A UAGADGU	913	GCAGGAU U CUACCAU
674	ACUUUAU A GAUGUUU	914	CAGGAU C UACCAUA
680	UAGADGU U UUGGUUC	916	GGADUCU A CCAUAUA
681	AGAUGU U UUGGUCA	921	CUACCAU A UAUUGAA
682	GAUGUUU U UGUUCAU	923	ACCAUAU A UUGAACA
683	AUGUUU U GUUCAU	925	CAUAUAU U GAACAAC
686	UUUUGU C CAUUUG	943	AAAGCAU C AUAUAUA
687	UUUUGU C AUUUUGG	946	GCAUCAU U AUUAUCU
690	UGUUCAU U UUGGUAD	947	CAUCAU A UUAUCUU
691	GUUCAU U UGGUAUA	949	UCAUAU U AUCUUUG
692	UUCAUU U GGUADAG	950	CAUAUAU A UCUUUGA

952 UUAUUAU C UUGACU  
954 AUUAUCU U UGACUA  
955 UUAUCU U GACUAA  
960 UUGACU C AAUOCC  
964 ACUCAAU U UCCUAC  
965 CUCAAU U CCUACU  
966 UCAAUU C CUACU  
969 AUUUCU C ACUCC  
973 CCUCACU U CUCCAGU  
974 CUACU C UCCAGG  
976 CACUUCU C CAGUGA  
983 CCAGUGU A GUAGAG  
986 GUGUAGU A UAGGCA  
988 GUAGU U AGGCAU  
989 UAGUAU A GGCAUG  
1007 CUGGCU A GGCAUA  
1013 UAGGCAU A AUGGAG  
1024 GGAGAGU A CAGAGG  
1032 CAGAGG A CACCGAG  
1044 GAGGAU C AAGACU  
1050 UCAAGU C UAUAUGA  
1052 AAGACU A UAUGAG  
1054 GACUAU A UGAGCA  
1072 AAGGCAU A UGCGAA  
1085 AACAAU C AAAGAA  
1103 GUGUGAU U AACUACA  
1104 UGUGAU A ACUACAG  
1108 AUUAACU A CAGUGUA  
1115 ACAGUGU A CUAGACU  
1118 GUGUACU A GACUUGA  
1123 CUAGACU U GACAGCA  
1139 AAGAACU A GAGGCUA  
1146 AGAGGCU A UCAAACA  
1148 AGGCUAU C AAACAUC  
1155 CAAACAU C AGCUAA  
1160 AUCAGCU U AADCCAA  
1161 UCAGCU A ADCCAA  
1164 GCUUAU C CAAAAGA  
1173 AAAAGAU A AUGAGU  
1181 AUGAGU A GAGCUU  
1187 UAGAGCU U UGAGUA  
1188 AGAGCU U GAGUAA  
1193 UUGAGU U AAUAAA  
1194 UUGAGU A AUAAAA

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Table 36: RSV (N) HH Ribozyme Sequence

nt. Position	HH Ribozyme Sequence
9	AUCUUUG CUGAUGAGGCCGAAAGGCCGAA AUUUGCC
21	UUGCUAA CUGAUGAGGCCGAAAGGCCGAA AGCCAUU
23	CUUUGCU CUGAUGAGGCCGAAAGGCCGAA AGAGCCA
24	ACUUUGC CUGAUGAGGCCGAAAGGCCGAA AAGAGCC
32	UCAACUU CUGAUGAGGCCGAAAGGCCGAA ACUUUGC
37	AUCAUUC CUGAUGAGGCCGAAAGGCCGAA ACUUGAC
45	UUGAGUG CUGAUGAGGCCGAAAGGCCGAA AUCAUUC
50	CUUUGUU CUGAUGAGGCCGAAAGGCCGAA AGUGUAU
60	AGAAAGU CUGAUGAGGCCGAAAGGCCGAA AUUUUUG
65	AUGACAG CUGAUGAGGCCGAAAGGCCGAA AGUUGAU
66	GAUGACA CUGAUGAGGCCGAAAGGCCGAA AAGUUGA
70	GCUGGAU CUGAUGAGGCCGAAAGGCCGAA ACAGAAAG
73	UUUGCUG CUGAUGAGGCCGAAAGGCCGAA AUGACAG
82	GAUGGUG CUGAUGAGGCCGAAAGGCCGAA AUUUGCU
89	UCCGUUG CUGAUGAGGCCGAAAGGCCGAA AUGGGUU
108	UCAAUAC CUGAUGAGGCCGAAAGGCCGAA AUUCCUU
111	GUADCAA CUGAUGAGGCCGAAAGGCCGAA ACUAUCU
113	GAGUAUC CUGAUGAGGCCGAAAGGCCGAA AUUUAUU
117	UUAGGAG CUGAUGAGGCCGAAAGGCCGAA AUCAUAU
120	UAUUUAG CUGAUGAGGCCGAAAGGCCGAA AGUAUCA
123	UCAUAUU CUGAUGAGGCCGAAAGGCCGAA AGGAGUA
126	ACADCAU CUGAUGAGGCCGAAAGGCCGAA AUUAGGA
127	CACADCA CUGAUGAGGCCGAAAGGCCGAA AAUUAGG
146	ACUUUUU CUGAUGAGGCCGAAAGGCCGAA AUGUGUU
150	CAUAACU CUGAUGAGGCCGAAAGGCCGAA AUUGAUG
154	GCCACAU CUGAUGAGGCCGAAAGGCCGAA ACUUUUU
155	UGCCACA CUGAUGAGGCCGAAAGGCCGAA AACUUUU
166	GAUUAAU CUGAUGAGGCCGAAAGGCCGAA ACAUGCC
167	UGAUUAA CUGAUGAGGCCGAAAGGCCGAA AACAUUC
169	UGUGAUU CUGAUGAGGCCGAAAGGCCGAA AUUACAU
170	CUGUGAU CUGAUGAGGCCGAAAGGCCGAA AAUAACA
173	CUUCUGU CUGAUGAGGCCGAAAGGCCGAA AUUAAUA
186	UUUUGAU CUGAUGAGGCCGAAAGGCCGAA AGCAUCU
189	AAUUUAU CUGAUGAGGCCGAAAGGCCGAA AUUAGCA
192	GUGAAUU CUGAUGAGGCCGAAAGGCCGAA AUGAUUA
196	CCCAGUG CUGAUGAGGCCGAAAGGCCGAA AUUUUUG
197	ACCCAGU CUGAUGAGGCCGAAAGGCCGAA AAUUUUU
205	ACCUAAU CUGAUGAGGCCGAAAGGCCGAA ACCCAGU
206	UACCUAU CUGAUGAGGCCGAAAGGCCGAA AACCCAG
209	ACAUAAC CUGAUGAGGCCGAAAGGCCGAA AUUAACC
213	UAUAACA CUGAUGAGGCCGAAAGGCCGAA ACCUAUU

217	CGCAU	UGAGGCGAAAGGCGAA	ACAUACC
218	UGCAUA	UGAGGCGAAAGGCGAA	AACAUAAC
220	CADCGCA	UGAGGCGAAAGGCGAA	AUAACAU
229	UAACCUA	UGAGGCGAAAGGCGAA	ACADCGC
231	CCUAACC	UGAGGCGAAAGGCGAA	AGACAUC
235	UCUCCU	UGAGGCGAAAGGCGAA	ACCUAGA
236	CUCUCC	UGAGGCGAAAGGCGAA	AACCUAG
254	GUUUUU	UGAGGCGAAAGGCGAA	ADGGUGU
260	CUCGAG	UGAGGCGAAAGGCGAA	ADUUUA
263	CADCCU	UGAGGCGAAAGGCGAA	AGUADUU
277	UACADGA	UGAGGCGAAAGGCGAA	ADCCCGC
279	UUACAUI	UGAGGCGAAAGGCGAA	AUAUCCC
284	UUGUUU	UGAGGCGAAAGGCGAA	ACADGAU
299	UUACAC	UGAGGCGAAAGGCGAA	ACUCCAU
305	GUGUGU	UGAGGCGAAAGGCGAA	ACADCUA
315	UCUGAC	UGAGGCGAAAGGCGAA	ADGUGUU
318	ADGUCU	UGAGGCGAAAGGCGAA	ACGADGU
326	UUCCAU	UGAGGCGAAAGGCGAA	ADGUCUU
327	UUUCCAU	UGAGGCGAAAGGCGAA	AADUGCU
346	CACUUA	UGAGGCGAAAGGCGAA	ADUUCAU
347	ACACUUC	UGAGGCGAAAGGCGAA	AADUUCA
355	CAAGUU	UGAGGCGAAAGGCGAA	ACACUUC
356	CCAAGU	UGAGGCGAAAGGCGAA	AACACUU
361	GCUUGC	UGAGGCGAAAGGCGAA	ADGUUA
370	AGUUGU	UGAGGCGAAAGGCGAA	AGCUUGC
371	CAGUUG	UGAGGCGAAAGGCGAA	AAGCUUG
383	UGAUUG	UGAGGCGAAAGGCGAA	ADUUCAG
384	UUGAUU	UGAGGCGAAAGGCGAA	AADUUCA
389	CAAGUU	UGAGGCGAAAGGCGAA	ADUUGAA
395	CUACUC	UGAGGCGAAAGGCGAA	AUGUUGA
401	UAGAUUC	UGAGGCGAAAGGCGAA	ADCUCAA
406	UUUCCA	UGAGGCGAAAGGCGAA	AUUUUAU
408	GAUUUC	UGAGGCGAAAGGCGAA	AGAUUCU
415	UUUGAG	UGAGGCGAAAGGCGAA	AUUUUUU
418	UUUUUG	UGAGGCGAAAGGCGAA	AGGAUUU
431	UUUCUU	UGAGGCGAAAGGCGAA	AGCAUUU
449	CUGGAC	UGAGGCGAAAGGCGAA	ACCUCC
453	UAUUCG	UGAGGCGAAAGGCGAA	AGCUAAC
460	AUGCCUG	UGAGGCGAAAGGCGAA	AUUCUGG
472	AUCAGGA	UGAGGCGAAAGGCGAA	AGUUAUG
474	CAADCA	UGAGGCGAAAGGCGAA	AGAGUCA
480	ADCCAC	UGAGGCGAAAGGCGAA	AUCAGGA
491	AUAUAU	UGAGGCGAAAGGCGAA	AUCAUCC
494	UACAUAA	UGAGGCGAAAGGCGAA	AUAUUA
496	UAUACAU	UGAGGCGAAAGGCGAA	AUAUAU
497	CUAUCA	UGAGGCGAAAGGCGAA	AUAUAUA
501	GUUGUA	UGAGGCGAAAGGCGAA	ACAUUAU
503	ADGUCG	UGAGGCGAAAGGCGAA	AUAUAUA
511	UAUAUCU	UGAGGCGAAAGGCGAA	ADGUCUG

512	UUUUUAC	CUGAUGAGGCGGAAAGGCCGAA	AADGCTG
515	UAGUUU	CUGAUGAGGCGGAAAGGCCGAA	ACTAADG
518	AUUUAGU	CUGAUGAGGCGGAAAGGCCGAA	AUUACUA
522	GUUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
526	UGUUUU	CUGAUGAGGCGGAAAGGCCGAA	AUUUAGU
527	UGUUUU	CUGAUGAGGCGGAAAGGCCGAA	AUUUAGU
544	AAGACCA	CUGAUGAGGCGGAAAGGCCGAA	AUUUAGU
549	GUUUUU	CUGAUGAGGCGGAAAGGCCGAA	AUUUAGU
551	UGUUUU	CUGAUGAGGCGGAAAGGCCGAA	AUUUAGU
552	ACGGGUG	CUGAUGAGGCGGAAAGGCCGAA	AAGACCA
563	GUUUUU	CUGAUGAGGCGGAAAGGCCGAA	AUUUAGU
564	GUUUUU	CUGAUGAGGCGGAAAGGCCGAA	AUUUAGU
573	ACUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
576	AGUUUU	CUGAUGAGGCGGAAAGGCCGAA	AUUUAGU
581	UUUUUU	CUGAUGAGGCGGAAAGGCCGAA	ACUUUU
584	CAUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
603	CCUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
604	GUUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
613	GGUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
614	UGUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
617	CCUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
629	UGUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
640	UUUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
641	UUUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
643	CAUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
652	UUUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
653	GUUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
663	AAGUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
670	AUUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
671	CAUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
672	ACUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
674	AAUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
680	GAUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
681	UGUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
682	ADUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
683	ADUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
686	CAUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
687	CCUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
690	AUUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
691	UUUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
692	UUUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
696	UUUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
698	AUUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
706	GGUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
708	UGUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
709	UUUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
711	UUUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
726	UUUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU
731	UUUUUU	CUGAUGAGGCGGAAAGGCCGAA	AGUUUU

740	CUGCAA	CUGAUGAGGCGAAAGGCGAA	AUCCCUU
741	CCUGCA	CUGAUGAGGCGAAAGGCGAA	AAUCCCU
742	UCCUGCA	CUGAUGAGGCGAAAGGCGAA	AAAUCCC
743	AUCCUGC	CUGAUGAGGCGAAAGGCGAA	AAAUCCC
751	CAUAAAC	CUGAUGAGGCGAAAGGCGAA	AUCCUGC
754	AUUCAU	CUGAUGAGGCGAAAGGCGAA	ACAADCC
755	CAUUCU	CUGAUGAGGCGAAAGGCGAA	AACAADC
756	GCAUUC	CUGAUGAGGCGAAAGGCGAA	AAACAAC
766	UGACCA	CUGAUGAGGCGAAAGGCGAA	AGGCAUU
787	CCACCG	CUGAUGAGGCGAAAGGCGAA	ACAUCAC
788	CCACCG	CUGAUGAGGCGAAAGGCGAA	AACAACA
800	UUGCUA	CUGAUGAGGCGAAAGGCGAA	ACUCCCC
802	UUUUGCU	CUGAUGAGGCGAAAGGCGAA	AGACUCC
803	AUUUGUC	CUGAUGAGGCGAAAGGCGAA	AAGACUC
811	UUUAACU	CUGAUGAGGCGAAAGGCGAA	AUUUUGC
815	UAUUUU	CUGAUGAGGCGAAAGGCGAA	ACUGAUU
816	AUAUUU	CUGAUGAGGCGAAAGGCGAA	AACUGAU
822	AACAUA	CUGAUGAGGCGAAAGGCGAA	AUUUUUA
824	CUAACA	CUGAUGAGGCGAAAGGCGAA	AUAUUUU
825	CCUAACA	CUGAUGAGGCGAAAGGCGAA	AAUAUUU
829	AUGUCCU	CUGAUGAGGCGAAAGGCGAA	ACAUAUU
830	CAUGUCC	CUGAUGAGGCGAAAGGCGAA	AACAUAU
840	UGCACAC	CUGAUGAGGCGAAAGGCGAA	AGCAUGU
866	CCUCAAC	CUGAUGAGGCGAAAGGCGAA	ACUUGUU
869	AAACUCC	CUGAUGAGGCGAAAGGCGAA	ACAACUU
875	AUUCUA	CUGAUGAGGCGAAAGGCGAA	ACCUCAA
876	UAUUCU	CUGAUGAGGCGAAAGGCGAA	AAACUCA
877	AUAUUA	CUGAUGAGGCGAAAGGCGAA	AAACUCC
883	UUGGCA	CUGAUGAGGCGAAAGGCGAA	AUUCUAU
895	AACACC	CUGAUGAGGCGAAAGGCGAA	AUUUUUG
913	AUGGUAG	CUGAUGAGGCGAAAGGCGAA	AUCCUGC
914	UAUGGUA	CUGAUGAGGCGAAAGGCGAA	AAUCCUG
916	UAUAUGG	CUGAUGAGGCGAAAGGCGAA	AGAUAUC
921	UUCAAUA	CUGAUGAGGCGAAAGGCGAA	AUGGUAG
923	UGUUCAA	CUGAUGAGGCGAAAGGCGAA	AUAUGGU
925	GUUGUUC	CUGAUGAGGCGAAAGGCGAA	AUAUAUG
943	UAUAUAU	CUGAUGAGGCGAAAGGCGAA	AUGCUUU
946	AGAUAUU	CUGAUGAGGCGAAAGGCGAA	AUGAUGC
947	AAGAUA	CUGAUGAGGCGAAAGGCGAA	AADGAUG
949	CAAAGAU	CUGAUGAGGCGAAAGGCGAA	AUAUAUG
950	UCAAGA	CUGAUGAGGCGAAAGGCGAA	AAUAADG
952	AGUCAA	CUGAUGAGGCGAAAGGCGAA	AUAUAUA
954	UGAGUCA	CUGAUGAGGCGAAAGGCGAA	AGAUAUU
955	UUGAGUC	CUGAUGAGGCGAAAGGCGAA	AAGAUAU
960	GGAAAUU	CUGAUGAGGCGAAAGGCGAA	AGUCAAA
964	GUGAGGA	CUGAUGAGGCGAAAGGCGAA	AUUGAGU
965	AGUGAGG	CUGAUGAGGCGAAAGGCGAA	AADUGAG
966	AAGUGAG	CUGAUGAGGCGAAAGGCGAA	AAAUUGA
969	GAGAAGU	CUGAUGAGGCGAAAGGCGAA	AGGAAAU



973	ACUGGAG	CUGAUGAGGCGGAAAGGCGGAA	AGUGAGG
974	CACUGGA	CUGAUGAGGCGGAAAGGCGGAA	AAGUGAG
976	UACACUG	CUGAUGAGGCGGAAAGGCGGAA	ACAAGUG
983	CUAAUAC	CUGAUGAGGCGGAAAGGCGGAA	ACACUGG
986	UGGCUAA	CUGAUGAGGCGGAAAGGCGGAA	ACTACAC
988	AUUGCCU	CUGAUGAGGCGGAAAGGCGGAA	AACTAC
989	CAUUGCC	CUGAUGAGGCGGAAAGGCGGAA	AACTAC
1007	UUAUGCC	CUGAUGAGGCGGAAAGGCGGAA	AGGCGAG
1013	CUCCCAU	CUGAUGAGGCGGAAAGGCGGAA	AUGGCUA
1024	ACCUCCU	CUGAUGAGGCGGAAAGGCGGAA	ACUCCGC
1032	CUCCGUG	CUGAUGAGGCGGAAAGGCGGAA	ACCUCCG
1044	AGADCUU	CUGAUGAGGCGGAAAGGCGGAA	AUUCUCC
1050	UCADUA	CUGAUGAGGCGGAAAGGCGGAA	AUCUUGA
1052	CAUCAUA	CUGAUGAGGCGGAAAGGCGGAA	AGAUCCU
1054	UGCADCA	CUGAUGAGGCGGAAAGGCGGAA	AUAGADC
1072	UUCAGCA	CUGAUGAGGCGGAAAGGCGGAA	AUGGCUU
1085	UUUCUUU	CUGAUGAGGCGGAAAGGCGGAA	AGUUGUU
1103	UGUAGUU	CUGAUGAGGCGGAAAGGCGGAA	AUCACAC
1104	CUGUAGU	CUGAUGAGGCGGAAAGGCGGAA	AAUACA
1108	UACACUG	CUGAUGAGGCGGAAAGGCGGAA	AGUUAUU
1115	AGGCUAG	CUGAUGAGGCGGAAAGGCGGAA	ACACUGU
1118	UCAAGUC	CUGAUGAGGCGGAAAGGCGGAA	AGUACAC
1123	UGGUGUC	CUGAUGAGGCGGAAAGGCGGAA	AGGCUAG
1139	UAGCCUC	CUGAUGAGGCGGAAAGGCGGAA	AGUUCUU
1146	UGUUGA	CUGAUGAGGCGGAAAGGCGGAA	AGCCUCU
1148	GAUGUUU	CUGAUGAGGCGGAAAGGCGGAA	AUAGCCU
1155	UUAAGCU	CUGAUGAGGCGGAAAGGCGGAA	AUGUUUG
1160	UUGGAUU	CUGAUGAGGCGGAAAGGCGGAA	AGGCGAU
1161	UUUGGAU	CUGAUGAGGCGGAAAGGCGGAA	AAGGCGA
1154	UCUUUUG	CUGAUGAGGCGGAAAGGCGGAA	AUUAAGC
1173	ACAUCAU	CUGAUGAGGCGGAAAGGCGGAA	AUCUUUU
1181	AAAGCUC	CUGAUGAGGCGGAAAGGCGGAA	ACAUCAU
1187	UAAUCUA	CUGAUGAGGCGGAAAGGCGGAA	AGGCUUA
1188	UUAACUC	CUGAUGAGGCGGAAAGGCGGAA	AAGCUCU
1193	UUUUUAU	CUGAUGAGGCGGAAAGGCGGAA	ACUCAA
1194	UUUUUAU	CUGAUGAGGCGGAAAGGCGGAA	AAACCAA

Table 37: RSV (1D) HP Ribozyme/Substrate Sequence

nt. Position	HP Ribozyme Sequence	Substrate
70	CUGUGAUC AGAA GUCUUU ACCAGAGAAACACACGUGUGUGUACUUAUCCUGUA	AAAGACU GAU GAUCACAG
91	CAGUGBAC AGAA GUCUCA ACCAGAGAAACACACGUGUGUGUACUUAUCCUGUA	UAGACC GUU GUCACUUG
472	CAGGCUCC AGAA GBAUUA ACCAGAGAAACACACGUGUGUGUACUUAUCCUGUA	UAGUCCA GAU GAGGCCUG

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Table 38: RSV (N) HP Ribozyme/Substrate Sequence

nt. Position	Hairpin Ribozyme Sequence	Substrate
476	AUCCCAUA AGAA GAAAGG ACCAGAGAAACACACGUGUGGUAUAUAUACCUUGUA	CUUUCU GAU UGUUGAUU
540	AAGACCAU AGAA GUCCCC ACCAGAGAAACACACGUGUGGUAUAUAUACCUUGUA	GGGUAUA GAU CUGGUCUU
554	CUAAUCAC AGAA GUAAAG ACCAGAGAAACACACGUGUGGUAUAUAUACCUUGUA	UCUUAUA GGC GUAAUUG
636	UUCAUAGA AGAA GUUUGC ACCAGAGAAACACACGUGUGGUAUAUAUACCUUGUA	GGCAUAU GCU UCUAUUUA
998	CCUAGGCC AGAA GCAUUG ACCAGAGAAACACACGUGUGGUAUAUAUACCUUGUA	CAUUGCU GCU GGUUUGG
1156	UUUGAUUA AGAA GAUUAU ACCAGAGAAACACACGUGUGGUAUAUAUACCUUGUA	AAUAUAU GCU UAAUCCAA

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Table 39: Large-Scale Synthesis

Sequence	Activator [Added/Final] (min)	Amidite [Added/Final] (min)	Time*	% Full Length Product
A <sub>9</sub> T	T [0.50/0.33]	[0.1/0.02]	15 m	85
A <sub>9</sub> T	S [0.25/0.17]	[0.1/0.02]	15 m	89
(GGU) <sub>3</sub> GGT	T [0.50/0.33]	[0.1/0.02]	15 m	78
(GGU) <sub>3</sub> GGT	S [0.25/0.17]	[0.1/0.02]	15 m	81
C <sub>9</sub> T	T [0.50/0.33]	[0.1/0.02]	15 m	90
C <sub>9</sub> T	S [0.25/0.17]	[0.1/0.02]	15 m	97
U <sub>9</sub> T	T [0.50/0.33]	[0.1/0.02]	15 m	80
U <sub>9</sub> T	S [0.25/0.17]	[0.1/0.02]	15 m	85
A (36-mer)	T [0.50/0.33]	[0.1/0.02]	15/15m	21
A (36-mer)	S [0.25/0.17]	[0.1/0.02]	15/15 m	25
A (36-mer)	S [0.50/0.24]	[0.1/0.03]	15/15 m	25
A (36-mer)	S [0.50/0.18]	[0.1/0.05]	15/15 m	38
A (36-mer)	S [0.50/0.18]	[0.1/0.05]	10/5 m	42

\*Where two coupling times are indicated the first refers to RNA coupling and the second to 2'-O-methyl coupling. S = 5-S-Ethyltetrazole, T = tetrazole activator. A is 5'-ucu ccA UCU GAU GAG GCC GAA AGG CCG AAA Auc ccu -3' where lowercase represents 2'-O-methylnucleotides.

Table 40: Base Deprotection

Sequence	Deprotection Reagent	Time (min)	T °C	% Full Length Product
iBu(GGU) <sub>4</sub>	NH <sub>4</sub> OH/EtOH	16 h	55	62.5
	MA	10 m	65	62.7
	AMA	10 m	65	74.8
	MA	10 m	55	75.0
	AMA	10 m	55	77.2
iPrP(GGU) <sub>4</sub>	NH <sub>4</sub> OH/EtOH	4 h	65	44.8
	MA	10 m	65	65.9
	AMA	10 m	65	59.8
	MA	10 m	55	61.3
	AMA	10 m	55	60.1
C <sub>9</sub> U	NH <sub>4</sub> OH/EtOH	4 h	65	75.2
	MA	10 m	65	79.1
	AMA	10 m	65	77.1
	MA	10 m	55	79.8
	AMA	10 m	55	75.5
A (36-mer)	NH <sub>4</sub> OH/EtOH	4 h	65	22.7
	MA	10 m	65	28.9

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Table 41: 2'-O-Alkylsilyl Deprotection

Sequence	Deprotection Reagent	Time (min)	T °C	% Full Length Product
AgT	TBAF	24 h	20	84.5
	1.4 M HF	0.5 h	65	81.0
(GGU) <sub>4</sub>	TBAF	24 h	20	60.9
	1.4 M HF	0.5 h	65	67.8
C <sub>10</sub>	TBAF	24 h	20	86.2
	1.4 M HF	0.5 h	65	86.1
U <sub>10</sub>	TBAF	24 h	20	84.8
	1.4 M HF	0.5 h	65	84.5
B (36-mer)	TBAF	24 h	20	25.2
	1.4 M HF	1.5 h	65	30.6
A (36-mer)	TBAF	24 h	20	29.7
	1.4 M HF	1.5 h	65	30.4

B is 5'- UCU CCA UCU GAU GAG GCC GAA AGG CCG AAA AUC CCU

-3'.

Table 42: NMR Data for UC Dimers containing  
Phosphorothioate Linkage

Synthesis #	Type	Delivery	Eq.	Wait	ASE (%)
3524	ribo	2 x 3 s	10.4	2 x 100 s	95.9
3525	ribo	2 x 3 s	10.4	2 x 75 s	92.6
3530	ribo	2 x 3 s	10.4	2 x 75 s	92.1
3526	ribo	1 x 5 s	08.6	1 x 300 s	100.0
3578	ribo	1 x 5 s	08.6	1 x 250 s	100.0
3529	ribo	1 x 5 s	08.6	1 x 150 s	73.7

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Table 43: NMR Data for 15-mer RNA containing  
Phosphorothioate Linkages

Synthesis #	Type	Delivery	Eq.	Wait	ASE (%)
3581	ribo	1 x 5 s	08.6	1 x 250 s	99.6
3663	ribo	2 x 4 s	13.8	2 x 300 s	100.0
3582	2'-O-Me	1 x 5 s	08.6	1 x 250 s	99.7
3668	2'-O-Me	2 x 4 s	13.8	2 x 300 s	99.8
3682	2'-O-Me	1 x 5 s	08.6	1 x 300 s	99.8

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Table 44. Kinetics of Self-Processing *In Vitro*

Self-Processing Constructs	k (min <sup>-1</sup> )*
HH	1.16 ± 0.08
HDV	0.56 ± 0.15
HP(GC)	0.36 ± 0.06
HP(GU)	0.054 ± 0.003

\* k represents the unimolecular rate constant for ribozyme self-cleavage determined from a non-linear, least-squares fit (KaleidaGraph, Synergy Software, Reading, PA) to the equation:

$$(\text{Fraction Uncleaved Transcript}) = \frac{1}{kt} (1 - e^{-kt})$$

The equation describes the extent of ribozyme processing in the presense of ongoing transcription (Long & Uhlenbeck, 1994 Proc. Natl. Acad. Sci. USA 91, 6977) as a function of time (t) and the unimolecular rate constant for cleavage (k). Each value of k represents the average (± range) of values determined from two experiments.

Table 45

Entry	Modification	$t_{1/2}$ (m) Activity ( $t_A$ )	$t_{1/2}$ (m) Stability ( $t_S$ )	$\beta = t_S/t_A$ $\times 10$
1	U4 & U7 = U	1	0.1	1
2	U4 & U7 = 2'-O-Me-U	4	260	650
3	U4 = 2'-CH <sub>2</sub> -U	6.5	120	180
4	U7 = 2'-CH <sub>2</sub> -U	8	280	350
5	U4 & U7 = 2'-CH <sub>2</sub> -U	9.5	120	130
6	U4 = 2'-CF <sub>2</sub> -U	5	320	640
7	U7 = 2'-CF <sub>2</sub> -U	4	220	550
8	U4 & U7 = 2'-CF <sub>2</sub> -U	20	320	160
9	U4 = 2'-F-U	4	320	800
10	U7 = 2'-F-U	8	400	500
11	U4 & U7 = 2'-F-U	4	300	750
12	U4 = 2'-C-Allyl-U	3	>500	>1700
13	U7 = 2'-C-Allyl-U	3	220	730
14	U4 & U7 = 2'-C-Allyl-U	3	120	400
15	U4 = 2'-araF-U	5	>500	>1000
16	U7 = 2'-araF-U	4	350	875
17	U4 & U7 = 2'-araF-U	15	500	330
18	U4 = 2'-NH <sub>2</sub> -U	10	500	500
19	U7 = 2'-NH <sub>2</sub> -U	5	500	1000
20	U4 & U7 = 2'-NH <sub>2</sub> -U	2	300	1500
21	U4 = dU	6	100	170
22	U4 & U7 = dU	4	240	600

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CLAIMSWhat is claimed is:

1. An enzymatic nucleic acid molecule which cleaves ICAM-1 mRNA, IL-5 mRNA, *rel A* mRNA, TNF- $\alpha$  mRNA sites shown in Table 23, 25, 27, or 28, CML associated mRNA selected from those identified as SEQ. ID NOS 1-25, or RSV mRNA or RSV genomic RNA in a region selected from the group consisting of 1C, 1B and N.
2. The enzymatic nucleic acid molecule of claim 1, the binding arms of which contain sequences complementary to any one of the sequences defined in any of those in Tables 2, 3, 6-9, 11, 13, 15-23, 27, 28, 31, 33, 34, 36, and 37.
3. The enzymatic nucleic acid molecule of claim 1 or 2, wherein said nucleic acid molecule is in a hammerhead motif.
4. The enzymatic nucleic acid molecule of claim 1 or 2, wherein said RNA molecule is in a hairpin, hepatitis delta virus, group 1 intron, *Neurospora* VS RNA or RNaseP RNA motif.
5. The enzymatic nucleic acid molecule of claim 1 or 2, comprising between 12 and 100 bases complementary to said mRNA or genomic RNA.
6. The enzymatic nucleic acid molecule of claim 5 comprising between 14 and 24 bases complementary to said mRNA or genomic RNA.
7. The enzymatic nucleic acid molecule of claim 1 or 2, comprising between 5 and 23 bases complementary to said mRNA or genomic RNA.
8. The enzymatic nucleic acid molecule of claim 7 comprising between 10 and 18 bases complementary to said mRNA or genomic RNA.
9. An enzymatic nucleic acid molecule consisting essentially of a sequence selected from the group of those shown in Tables 4-8, 10, 12, 14-16, 19-22, 24, 26-28, 30, 32, 34 and 36-38.
10. A mammalian cell including an enzymatic nucleic acid molecule of claims 1 or 2.

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11. The cell of claim 10, wherein said cell is a human cell.
12. An expression vector including nucleic acid encoding an enzymatic nucleic acid molecule or multiple enzymatic molecules of claims 1 or 2 in a manner which allows expression of that enzymatic RNA molecule(s) within a mammalian cell.
13. A mammalian cell including an expression vector of claim 12.
14. The cell of claim 13, wherein said cell is a human cell.
15. A method for treatment of a pathological condition related to the mRNA level of ICAM-1, IL-5, *rel A*, TNF- $\alpha$ , or RSV by administering to a patient an enzymatic nucleic acid molecule of claim 1 or 2.
16. A method for treatment of a pathological condition related to the mRNA level of ICAM-1, IL-5, *rel A*, TNF- $\alpha$ , or RSV by administering to a patient an expression vector of claim 12.
17. The method of claims 15 or 16, wherein said patient is a human.
18. The method of claim 17 wherein said condition is selected from the group consisting of atherosclerosis, myocardial infarction, stroke, restenosis, heart diseases, cancer, rheumatoid arthritis, asthma, reperfusion injury, inflammatory or autoimmune disorders, transplant rejection, myocardial ischemia, stroke, psoriasis, Kawasaki disease, HIV and AIDS, and septic shock.
19. A nucleoside selected from the group consisting of 5'-C-alkylnucleoside, 2'-deoxy-2'-alkylnucleoside, nucleoside 5'-deoxy-5'-dihalo-methylphosphonate, nucleoside 5'-deoxy-5'-difluoro-methylphosphonate, nucleoside 3'-deoxy-3'-dihalo-methylphosphonate, and 5',3'-dideoxy-5',3'-bis(dihalo)-methylphosphonate.
20. A nucleotide selected from the group consisting of 5'-C-alkylnucleotide, 2'-deoxy-2'-alkylnucleotide, 5'-deoxy-5'-dihalo-methylnucleotide, 5'-deoxy-5'-difluoro-methylnucleotide, 3'-deoxy-3'-dihalo-methylnucleotide, and 5',3'-dideoxy-5',3'-bis(dihalo)-methylphosphonate.

21. A nucleotide triphosphate comprising a nucleotide selected from the group consisting of 5'-C-alkylnucleotide, 2'-deoxy-2'-alkylnucleotide, 5'-deoxy-5'-dihalo-methylnucleotide, 5'-deoxy-5'-difluoro-methylnucleotide, 3'-deoxy-3'-dihalo-methylnucleotide, and 5',3'-dideoxy-5',3'-bis(dihalo)-methylphosphonate.
22. The 5'-C-alkylnucleoside of claim 19, wherein the sugar portion is in a talo configuration.
23. The 5'-C-alkylnucleoside of claim 19, wherein the sugar portion is in an allo configuration.
24. An oligonucleotide comprising a nucleotide selected from the group consisting of 5'-C-alkylnucleotide, 2'-deoxy-2'-alkylnucleotide, 5'-deoxy-5'-dihalo-methylnucleotide, 5'-deoxy-5'-difluoro-methylnucleotide, 3'-deoxy-3'-dihalo-methylnucleotide, and 5',3'-dideoxy-5',3'-bis(dihalo)-methylphosphonate.
25. An oligonucleotide comprising a moiety having the formula:
- wherein B is a nucleotide base or hydrogen; R1, R2 and R3 independently is selected from the group consisting of hydrogen, an alkyl group containing between 2 and 10 carbon atoms inclusive, an amine, an amino acid, and a peptide containing between 2 and 5 amino acids inclusive; and the zigzag lines are independently hydrogen or a bond.
26. An oligonucleotide comprising a 3'-amido or peptido group.
27. An oligonucleotide comprising a 5'-amido or peptido group.
28. The oligonucleotide of claim 24, 25, 26, or 27 having enzymatic activity.
29. Method for producing an enzymatic nucleic acid molecule having activity to cleave an RNA or single-stranded DNA molecule, comprising the step of forming said enzymatic molecule with at least one nucleotide having an alkyl group at its 5'-position or 2'-position.

- 5 30. Method for conversion of a protected allo sugar to a protected talo sugar, comprising the step of contacting said protected allo sugar with triphenyl phosphine, diethylazodicarboxylate, p-nitrobenzoic acid under inversion causing conditions to provide said protected talo sugar.
- 10 31. Method for the synthesis of a nucleoside 5' or a 3'-dihalo-methylphosphonate comprising the step of condensing a difluoromethylphosphonate-containing sugar with a pyrimidine or purine under conditions suitable for forming a nucleoside 5'- or 3'-difluoromethylphosphonate.
- 15 32. The oligonucleotide of claim 3, wherein the normal hammerhead U4 and/or U7 positions are substituted with 2'-NH-amino acid.
33. A method for the synthesis of RNA comprising the step of providing 5-S-alkyltetrazole at a delivered 0.1-1.0 M concentration for the activation of a RNA amidite during a coupling step for less than or equal to 10 minutes.
- 20 34. A method for the synthesis of RNA comprising the step of providing 5-S-alkyltetrazole at 0.15-0.35 M effective, or final, concentration for the activation of a RNA amidite during a coupling step for less than or equal to 10 minutes.
- 25 35. A method for the deprotection of RNA comprising the step of providing alkylamine (MA) or NH<sub>4</sub>OH/alkylamine (AMA) at between 60°C - 70°C for 5 to 15 minutes to remove any exocyclic amino protecting groups from protected RNA; wherein said alkyl is selected from the group consisting of methyl, ethyl, propyl and butyl.
- 30 36. A method for the deprotection of RNA alkylsilyl protecting groups comprising, contacting said groups with anhydrous triethylamine-hydrogen fluoride (aHF-TEA) trimethylamine or diisopropylethylamine at between 60 °C-70 °C for 0.25-24 h.
37. A method for the purification of an RNA molecule by passing said enzymatic RNA molecule over an HPLC column, wherein said HPCC column is an anion exchange chromatography column.

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38. Method for one pot deprotection of RNA comprising, contacting a protected base with anhydrous methyl amine at between 60 °C-70 °C for at least 5 min, cooling the resulting mixture and contacting said mixture with TEA-3HF reagents under conditions which remove a protecting group of the 2'-hydroxyl position.
39. Method for synthesizing RNA containing a phosphorothioate linkage comprising the step of contacting 6-10 equivalents of 3H-1,2-benzodithiole-3-one 1,1-dioxide (Beaucage reagent) with the growing RNA chain for 5 seconds with a reaction time of at least 300 seconds.
40. Method of synthesizing RNA containing a phosphorothioate linkage comprising the step of achieving coupling with 5-S-ethyltetrazole or 5-S-methyltetrazole prior to sulfurization.
41. Method of claims 38, 39 or 40 wherein said RNA is enzymatically active.
42. Method for synthesizing 2'-deoxy-2'-amino-nucleoside phosphoramidite, comprising the step of protecting the 2'-amino group with a N-phtaloyl group.
43. The method of claim 42 wherein the said nucleoside lacks a base.
44. Method for synthesis of RNA comprising the step of: protecting the 2'-position of a nucleotide during said synthesis with a (trimethylsilyl)ethoxymethyl (SEM) group.
45. Method for covalently linking a SEM group to the 2'-position of a nucleotide, comprising the step of: contacting a nucleoside with an SEM-containing molecule under SEM bonding conditions.
46. The method of claim 45, wherein said conditions comprise dibutyltin oxide and tetrabutylammonium fluoride and SEM-Cl.
47. Method for removal of an SEM group from a nucleoside molecule or an oligonucleotide, comprising the step of: contacting said molecule or oligonucleotide with boron trifluoride etherate ( $\text{BF}_3 \cdot \text{OEt}_2$ ) under SEM removing conditions.

48. The method of claim 57 wherein said ( $\text{BF}_3 \cdot \text{OEt}_2$ ) is provided in acetonitrile.

49. One or more vectors comprising

5 a first nucleic acid sequence encoding a first ribozyme having intramolecular or intermolecular cleaving activity, said first ribozyme being selected from the group consisting of a hammerhead, hairpin, hepatitis delta virus, *Neurospora* VS RNA, Group I, and RNaseP motif;

10 and a second nucleic acid sequence encoding a second ribozyme having intermolecular cleaving activity, said Second ribozyme being selected from the group consisting of a hammerhead, hairpin, hepatitis delta virus, *Neurospora* VS RNA, Group I, and RNaseP motif and said second nucleic acid being flanked by other  
15 nucleic acid sequences encoding RNA which is cleaved by said first ribozyme to release said second ribozyme from RNA encoded by said vector;

wherein said first and second nucleic acid sequences may be on the same or separate nucleic acid molecules, and said vector encodes mRNA or comprises RNA which lacks secondary structure which  
20 reduces release of said second ribozyme by more than 20%.

50. Cell comprising the vector of claim 49.

51. A transcribed non-naturally occurring RNA molecule, comprising a desired therapeutic RNA portion, wherein said molecule comprises an intramolecular stem formed by base-pairing interactions  
25 between a 3' region and 5' complementary nucleotides in said RNA, wherein said stem comprises at least 8 base pairs.

52. The RNA molecule of claim 51, wherein said molecule is transcribed by a RNA polymerase III based promoter system.

53. The RNA molecule of claim 51, wherein said molecule is transcribed  
30 by a type 2 pol III promoter system.

54. The RNA molecule of claim 51, wherein said molecule is a chimeric tRNA.



55. The RNA molecule of claim 53, said RNA having A and B boxes of a type 2 pol III promoter separated by between 0 and 300 bases.
56. The RNA molecule of claim 53, wherein said desired RNA molecule is at the 3' end of said B box.
- 5 57. The RNA molecule of claim 53, wherein said desired RNA molecule is in between the said A and the B box.
58. The RNA molecule of claim 53, wherein said desired RNA molecule includes said B box.
- 10 59. The RNA molecule of claim 51, wherein said desired RNA molecule is selected from the group consisting of antisense RNA, decoy RNA, therapeutic editing RNA, enzymatic RNA, agonist RNA and antagonist RNA.
60. The RNA molecule of claim 51, wherein said 5' terminus is able to base-pair with at least 12 bases of said 3' region.
- 15 61. The RNA molecule of claim 51, wherein said 5' terminus is able to base-pair with at least 15 bases of said 3' region.
62. DNA vector encoding the RNA molecule of claim 51
63. The vector of claim 62, wherein said vector is derived from an AAV or adeno virus.
- 20 64. RNA vector encoding the RNA molecule of claim 51.
65. The vector of claim 64, wherein said vector is derived from an alpha virus or retro virus.
66. The vector of claim 62 wherein the portions of the vector encoding said RNA function as a RNA pol III promoter.
- 25 67. Cell comprising the vector of claim 62.
68. Cell comprising the vector of claim 53.
69. Cell comprising the RNA of claim 51.

70. Method to provide a desired RNA molecule in a cell, comprising introducing said molecule into said cell a RNA comprising a desired RNA molecule, having a 5' terminus able to base pair with at least 8 bases of a 3' region of said RNA molecule.
- 5 71. The method of claim 70, wherein said introducing comprises providing a vector encoding said RNA molecule.
72. Hammerhead ribozyme having 2 or 3 base pairs in stem II with an interconnecting loop of 4 or more bases between said base pairs.
- 10 73. Hairpin ribozyme lacking a substrate moiety, comprising at least six bases in helix 2 and able to base-pair with a separate substrate RNA, wherein the said ribozyme comprises one or more bases 3' of helix 3 able to base-pair with the said substrate RNA to form a helix 5 and wherein the said ribozyme can cleave and/or ligate said separate RNA(s) in *trans*.
- 15 74. The ribozyme of claim 73, wherein said ribozyme comprises six bases in helix 2.
75. The ribozyme of claim 73, having the structure of Fig. 3, wherein each N and N' is independently any base and each dash may represent a hydrogen bond, r is 1-20, q is 2-20, o is 0 - 20, n is 1 - 4, and m is 1 - 20.
- 20 76. Method for increasing the activity of a hairpin ribozyme by providing one or more bases 3' of helix 3 able to base-pair with a substrate RNA to form a helix 5.
- 25 77. Trans-cleaving Hairpin ribozyme comprising at least 6 base pairs in helix 2 lacking a substrate RNA moiety.
78. Trans-ligating Hairpin ribozyme comprising at least 6 base pairs in helix 2 lacking a substrate RNA moiety.
79. The ribozyme of claim 73 having the structure of Fig. 73.
80. The ribozyme of claim 73 having the structure of Fig. 74.
- 30 81. A cell including the ribozyme of any of claims 73-80.

82. An expression vector comprising nucleic acid encoding the ribozyme of any of claims 73-80, in a manner which allows expression of that ribozyme within a cell.
83. A cell including an expression vector of claim 82.
- 5 84. Method for altering in vivo the nucleotide base sequence of a naturally occurring mutant nucleic acid molecule, comprising the steps of:
- 10 contacting said nucleic acid molecule in vivo with an oligonucleotide or peptide nucleic acid able to form a duplex or triplex molecule with said nucleic acid molecule, wherein formation of said duplex or triplex molecule directly, or after nucleic acid repair *in vivo*, causes at least one base in said nucleic acid molecule to be chemically modified to functionally alter the nucleotide base sequence of said nucleic acid sequence.
- 15 85. The method of claim 84, wherein said oligonucleotide is of a length sufficient to activate dsRNA deaminase in vivo to cause conversion of an adenine base to inosine in an RNA molecule.
- 20 86. The method of claim 84, wherein said oligonucleotide comprises an enzymatic nucleic acid molecule which is active to chemically modify a base.
87. The method claim 84, wherein said nucleic acid molecule is DNA or RNA.
88. The method of claim 84, wherein said oligonucleotide comprises a chemical mutagen.
- 25 89. The method of claim 88, wherein said mutagen is nitrous acid.
90. The method of claim 84 wherein said oligonucleotide causes deamination of 5-methylcytosine to thymidine, cytosine to uracil, or adenine to inosine, or methylation of cytosine to 5-methylcytosine.
- 30 91. The method of claim 84, wherein an endogenous mammalian editing system is co-opted to cause said chemical modification.

92. Method for introduction of enzymatic nucleic acid into a cell or tissue, comprising the steps of;

5 providing a complex of a first nucleic acid molecule encoding said enzymatic nucleic acid associated with a second nucleic acid molecule having sufficient complementarity with said first nucleic acid molecule so that it is able to form an R-loop base-paired structure under physiological conditions with said first nucleic acid molecule; wherein said R-loop is formed in a region of said first nucleic acid molecule at a location which promotes expression of  
10 RNA from said first nucleic acid under said conditions;

and contacting said complex with said cell or tissue under conditions in which said enzymatic nucleic acid molecule is produced in said cell or tissue.

- 15 93. Method for introduction of a desired nucleic acid into a cell or tissue, comprising the steps of;

20 providing a complex of a first nucleic acid molecule encoding said desired nucleic acid associated with a second nucleic acid molecule having sufficient complementarity with said first nucleic acid molecule so that it is able to form an R-loop base-paired structure under physiological conditions with said first nucleic acid molecule; wherein said first nucleic acid molecule lacks a promoter region and said R-loop is formed in a region of said first nucleic acid molecule at a location which promotes expression of RNA from said first nucleic acid under said conditions;

25 and contacting said complex with said cell or tissue under conditions in which said desired acid molecule is produced in said cell or tissue.

- 94 Method for introduction of a desired nucleic acid into a cell or tissue, comprising the steps of;

30 providing a complex of a first nucleic acid molecule encoding said enzymatic nucleic acid associated with a second nucleic acid molecule having sufficient complementarity with said first nucleic acid molecule so that it is able to form an R-loop base-paired

structure under physiological conditions with said first nucleic acid molecule; wherein said R-loop is formed in a region of said first nucleic acid molecule at a location which promotes expression of RNA from said first nucleic acid under said conditions;

5 and wherein said second nucleic acid further comprises a localization factor;

and contacting said complex with said cell or tissue under conditions in which said desired nucleic acid molecule is produced in said cell or tissue.

10 95. Complex of a first nucleic acid molecule encoding an enzymatic nucleic acid associated with a second nucleic acid molecule having sufficient complementarity with said first nucleic acid molecule so that it is able to form an R-loop base-paired structure under physiological conditions with said first nucleic acid molecule;  
15 wherein said R-loop is formed in a region of said first nucleic acid molecule at a location which promotes expression of RNA from said first nucleic acid under said conditions.

20 96. Complex of a first nucleic acid molecule encoding a desired nucleic acid associated with a second nucleic acid molecule having sufficient complementarity with said first nucleic acid molecule so that it is able to form an R-loop base-paired structure under physiological conditions with said first nucleic acid molecule; wherein said first nucleic acid molecule lacks a promoter region and said R-loop is formed in a region of said first nucleic acid  
25 molecule at a location which promotes expression of RNA from said first nucleic acid under said conditions.

30 97. Complex of a first nucleic acid molecule encoding an enzymatic nucleic acid associated with a second nucleic acid molecule having sufficient complementarity with said first nucleic acid molecule so that it is able to form an R-loop base-paired structure under physiological conditions with said first nucleic acid molecule; wherein said R-loop is formed in a region of said first nucleic acid molecule at a location which promotes expression of RNA from said

first nucleic acid under said conditions, and wherein said second nucleic acid further comprises a localization factor.

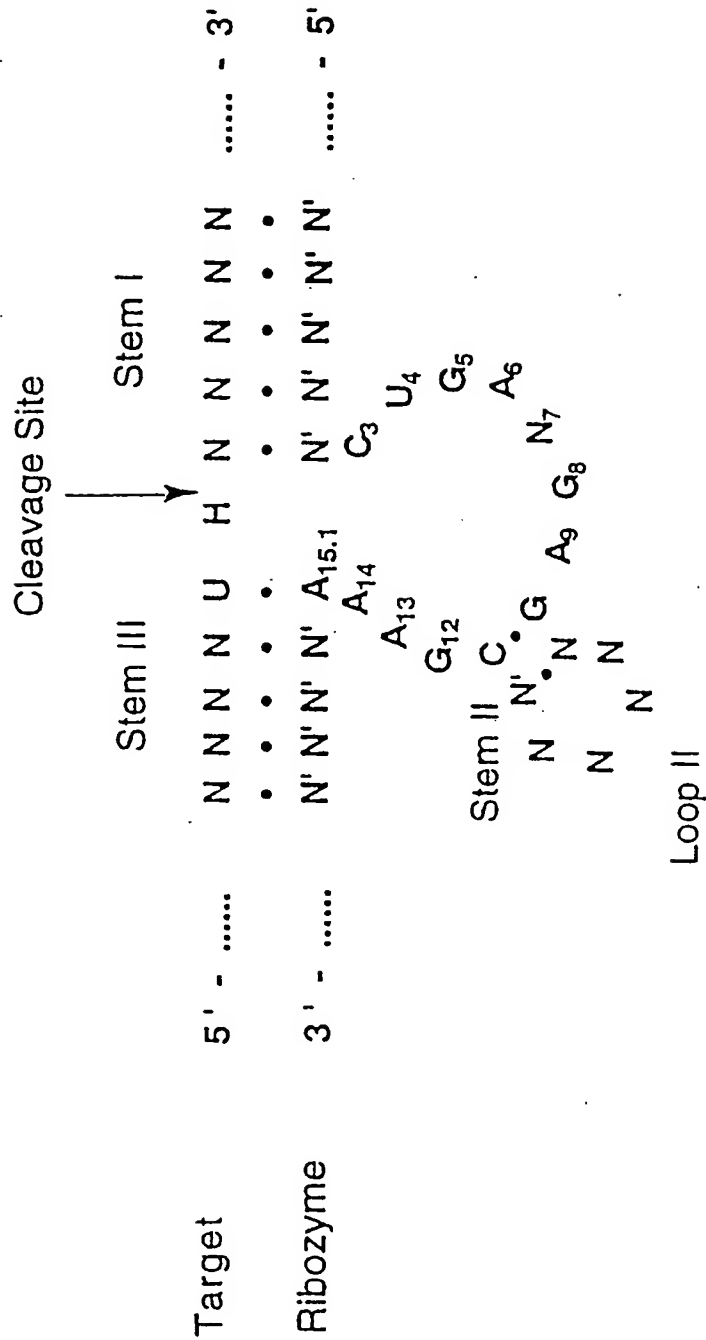
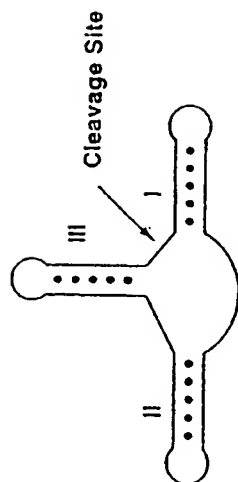


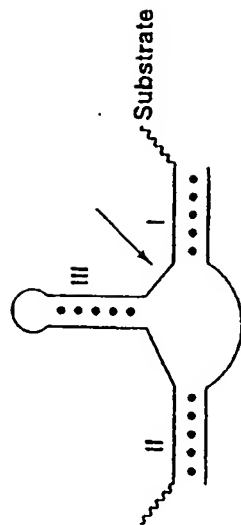
FIG. 1.

FIG. 2a.



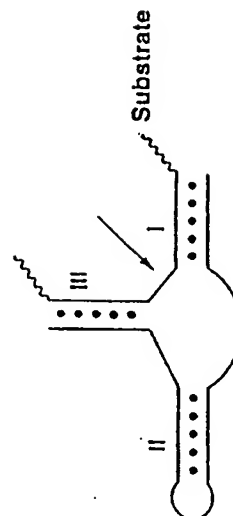
a

FIG. 2b.



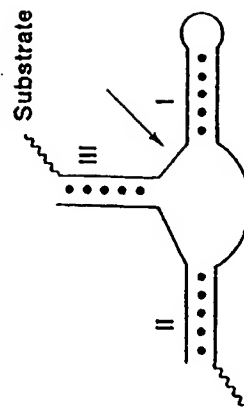
b

FIG. 2c.



c

FIG. 2d.



d



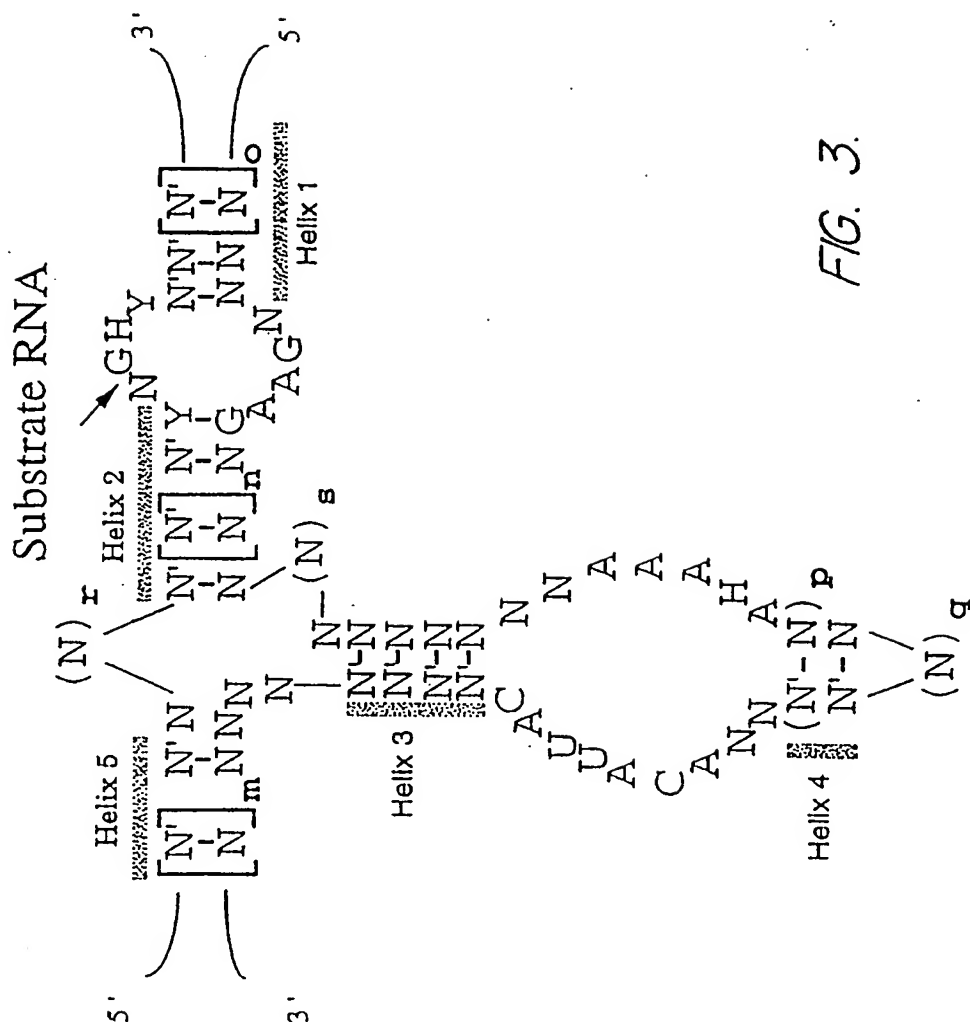
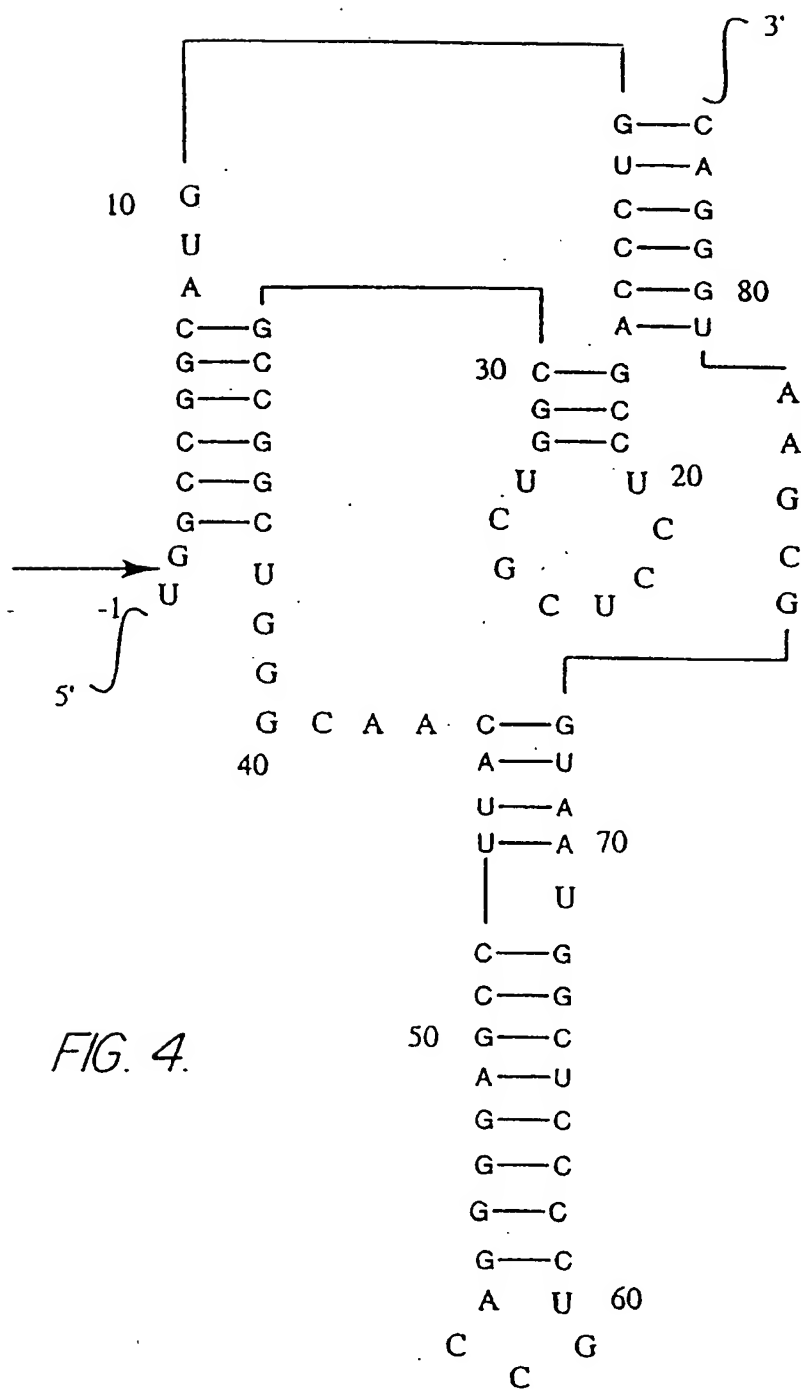


FIG. 3.

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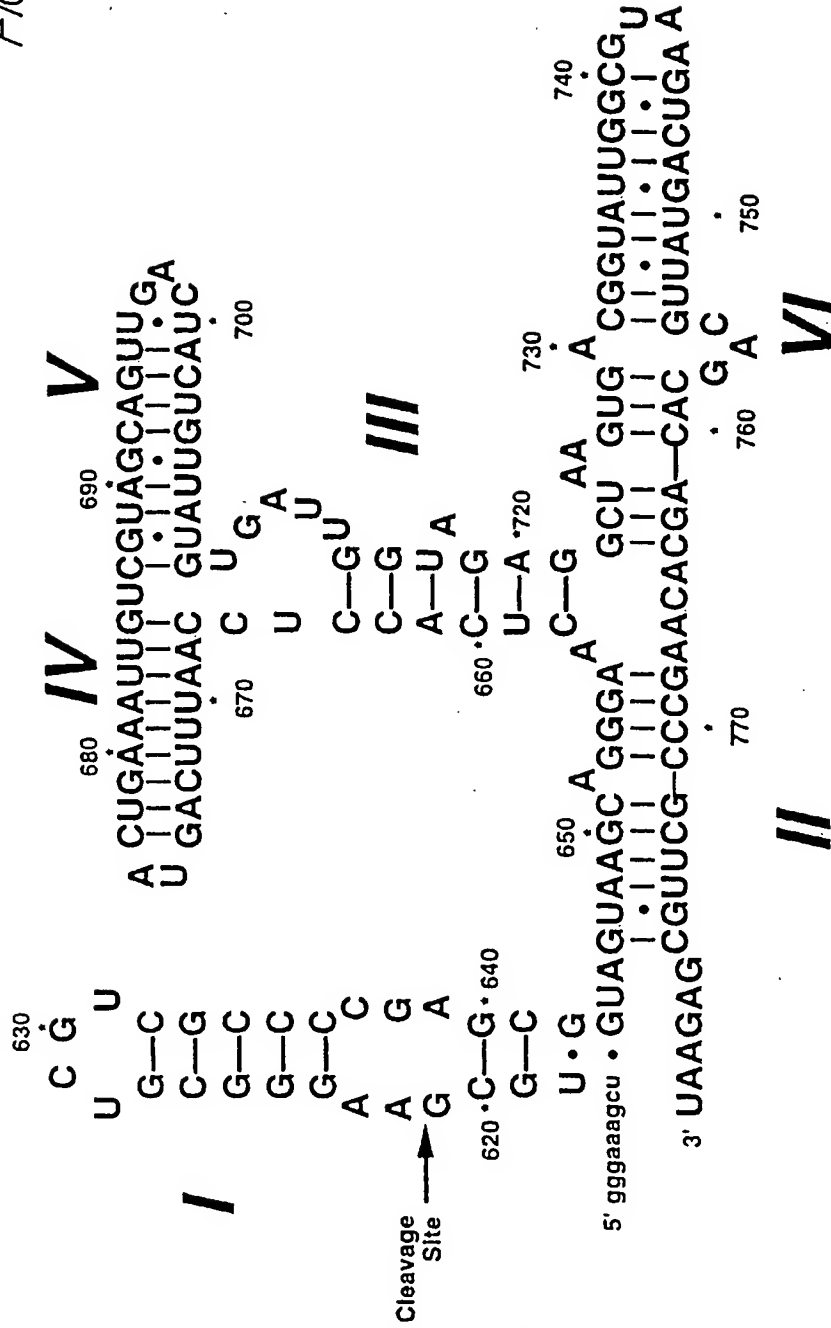
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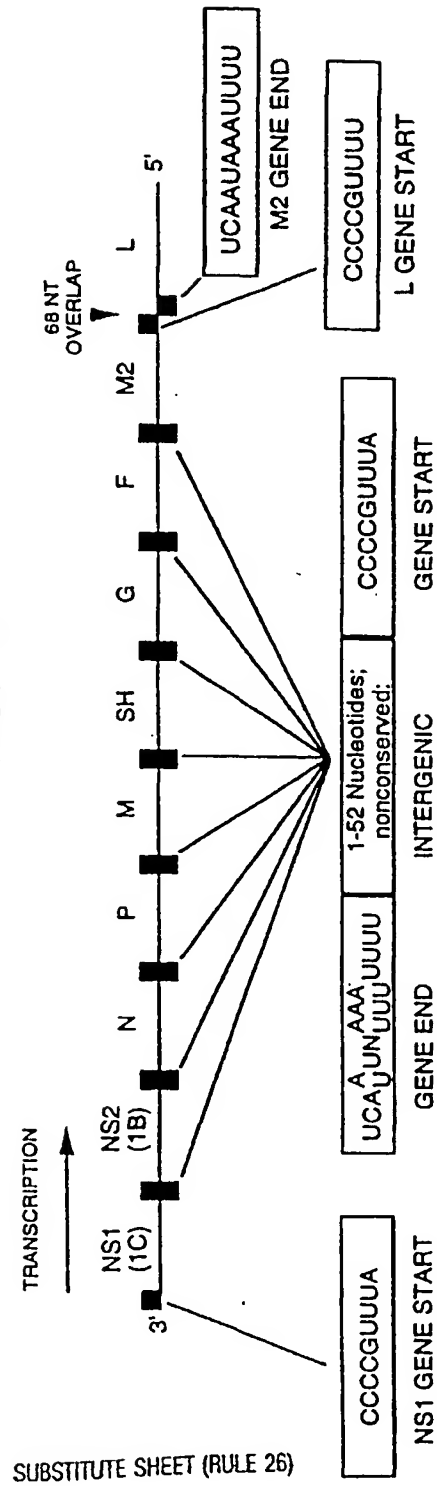
FIG. 5.



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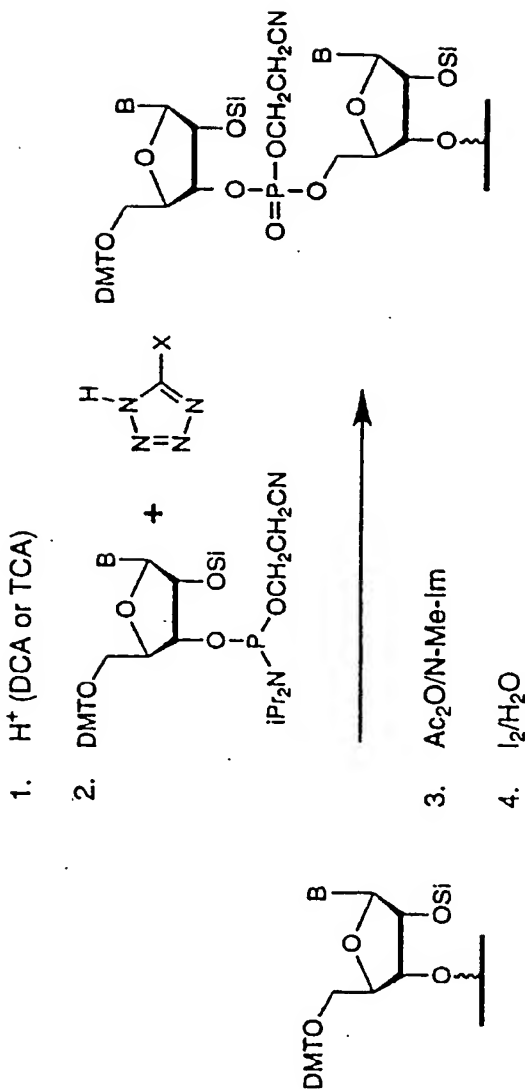
FIG. 6.



Adapted from Virology, Second Edition, Edited by B.N. Fields, 1990.

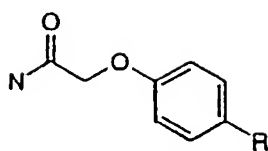
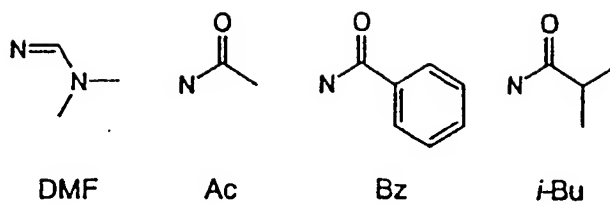
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FIG. 7.



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*FIG. 8.*

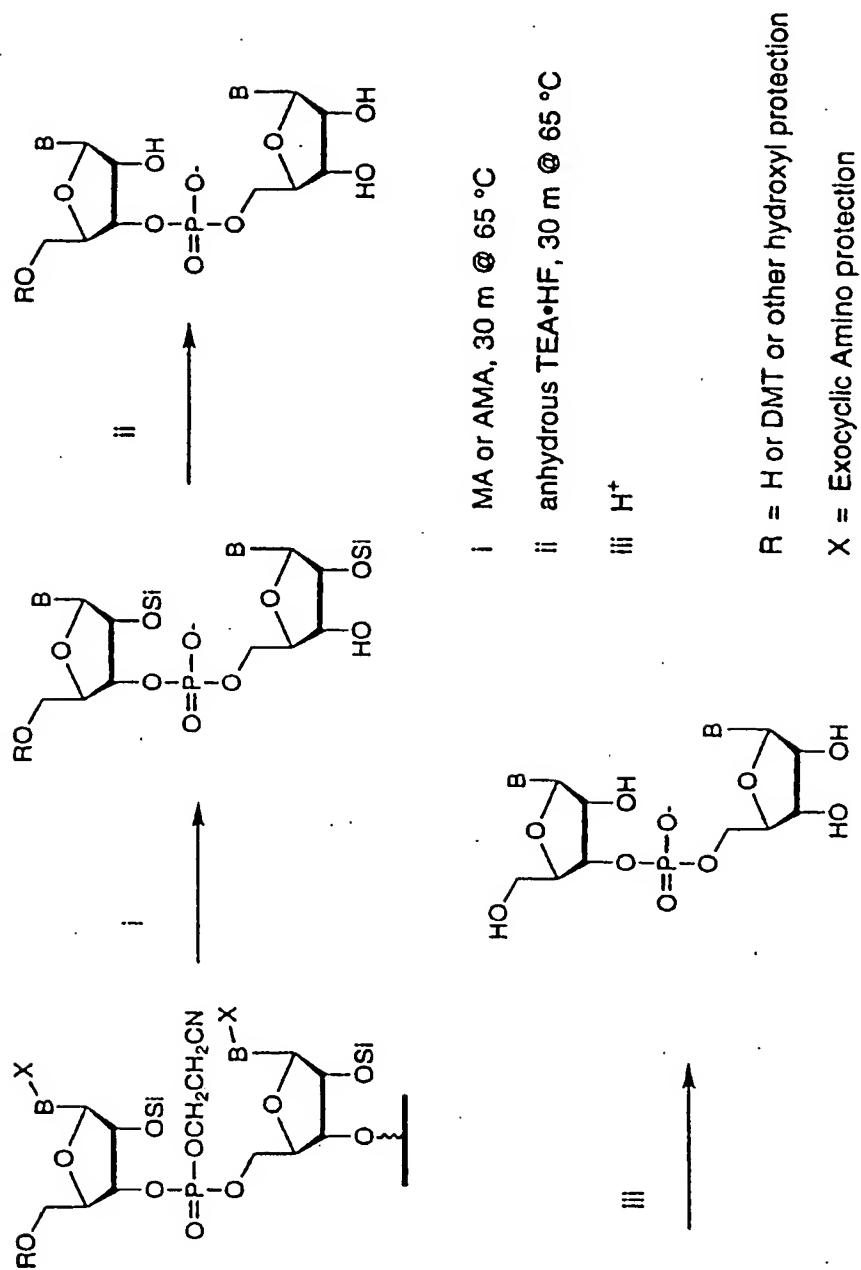
R = H = PAC

R = tBu = TAC

R = iPr = iPPAC

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FIG. 9.

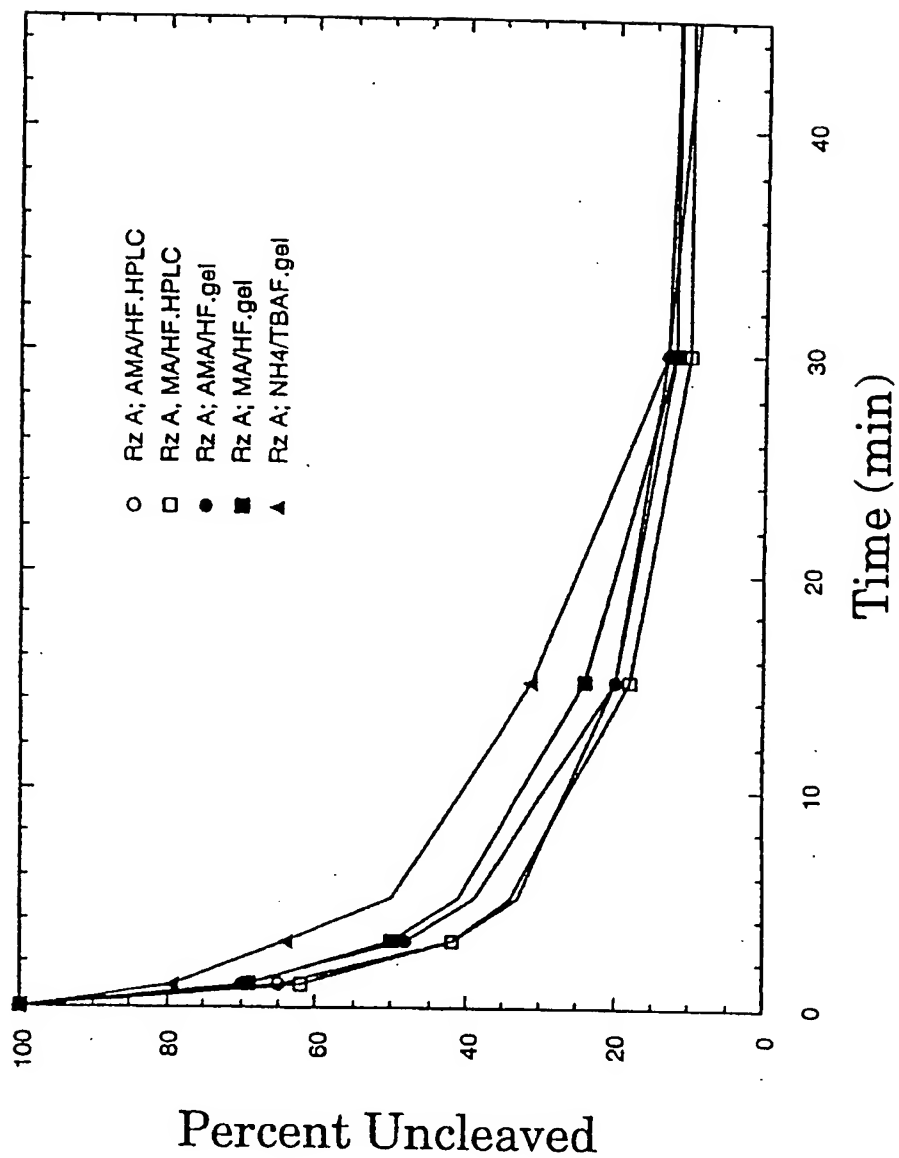


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FIG. 10.



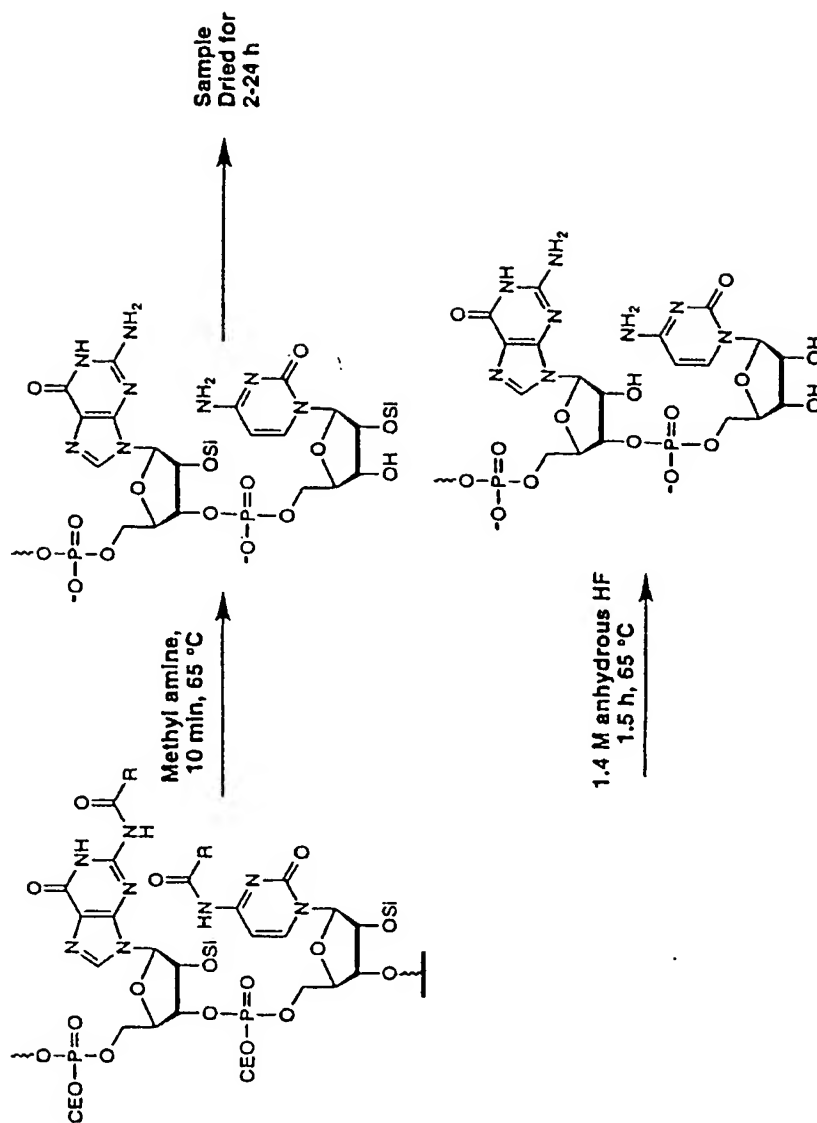
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FIG. 11.



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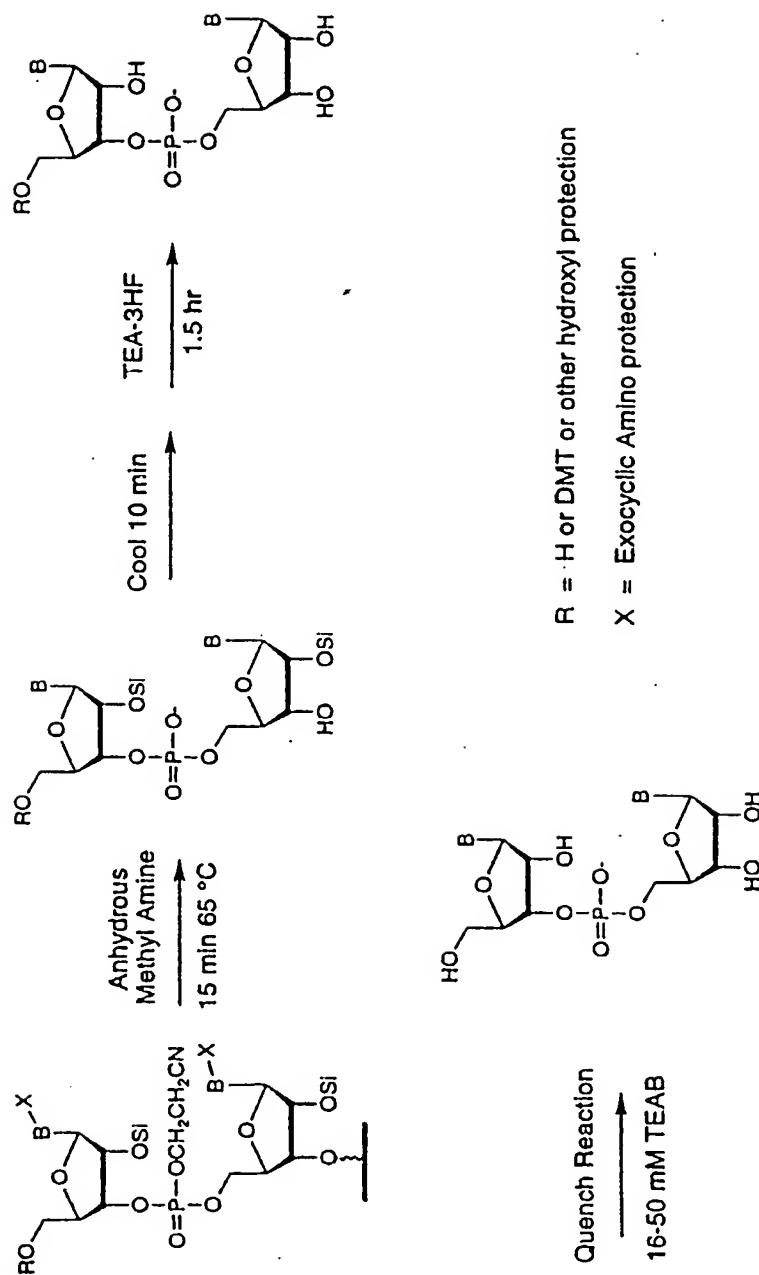


FIG. 12.

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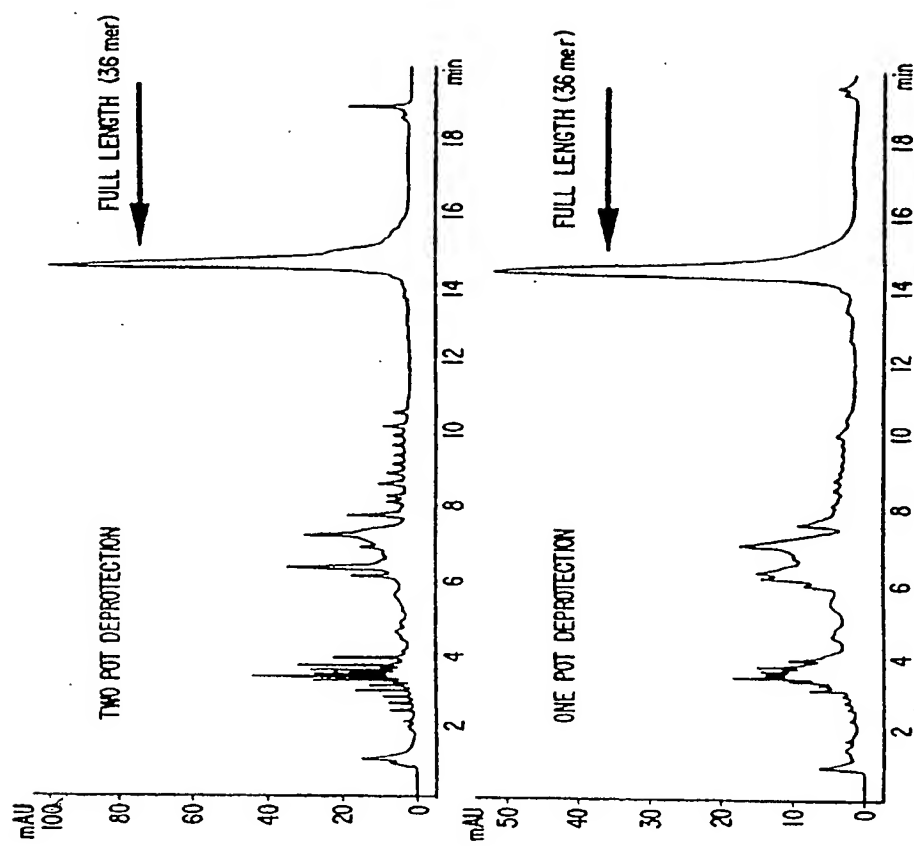


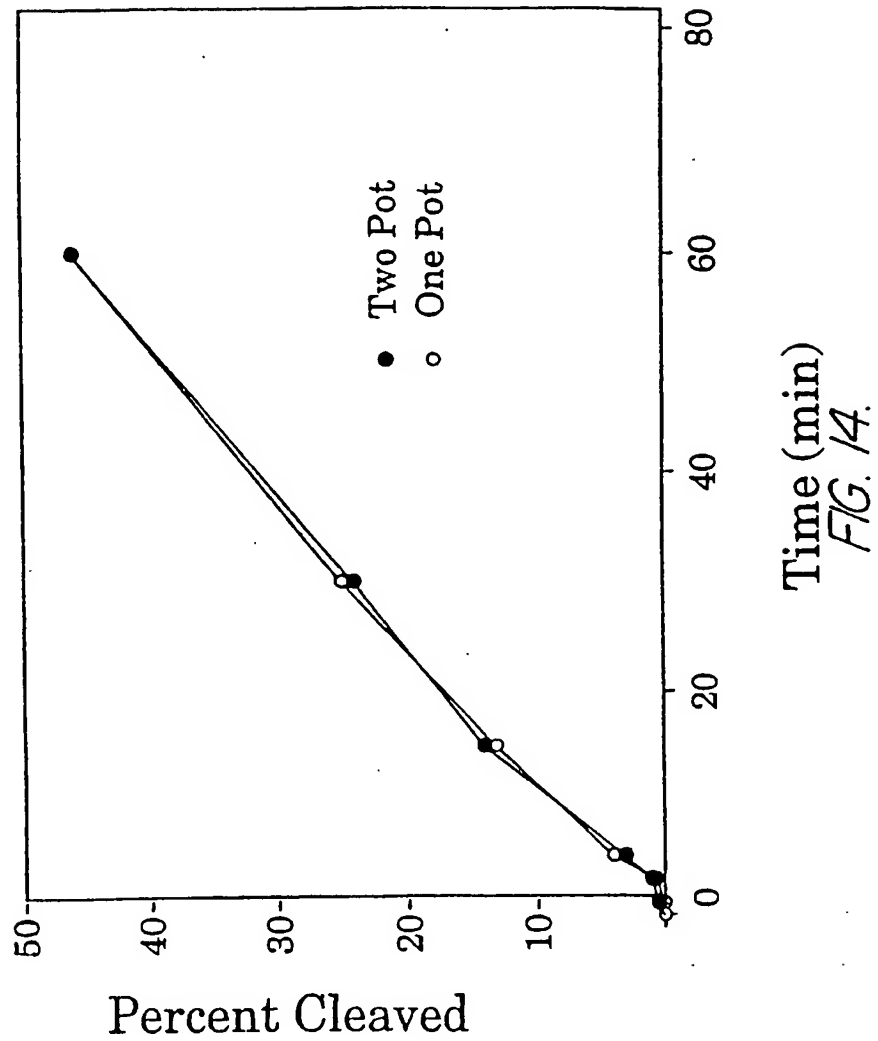
FIG. 13a.

FIG. 13b.

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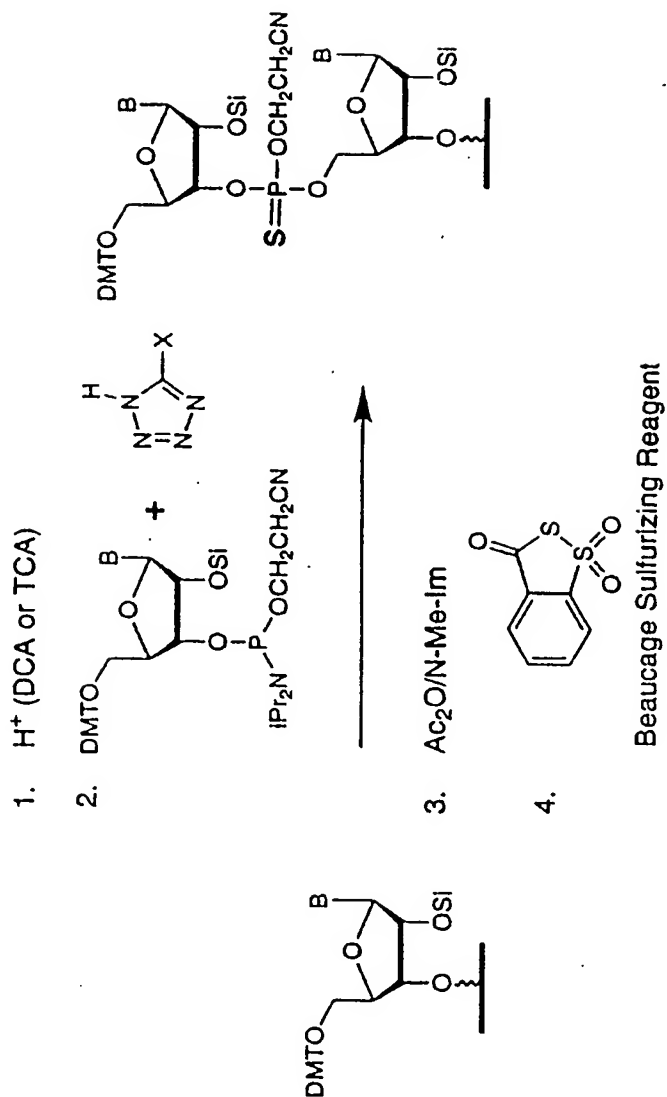


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FIG. 15.



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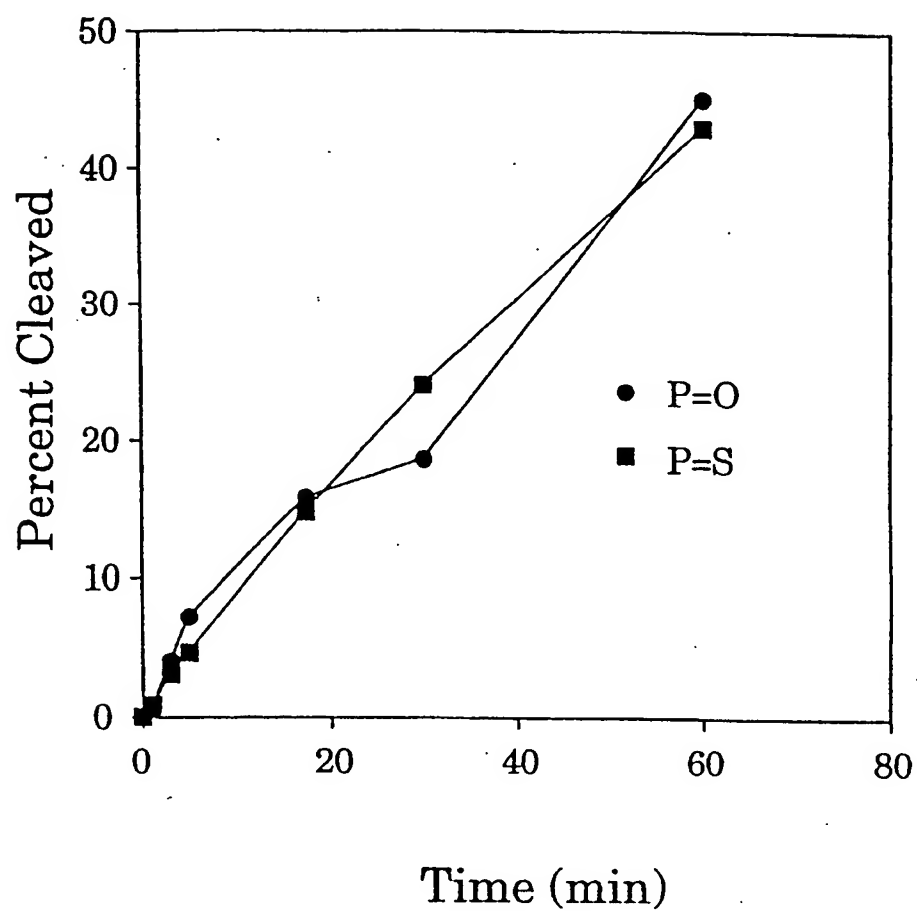
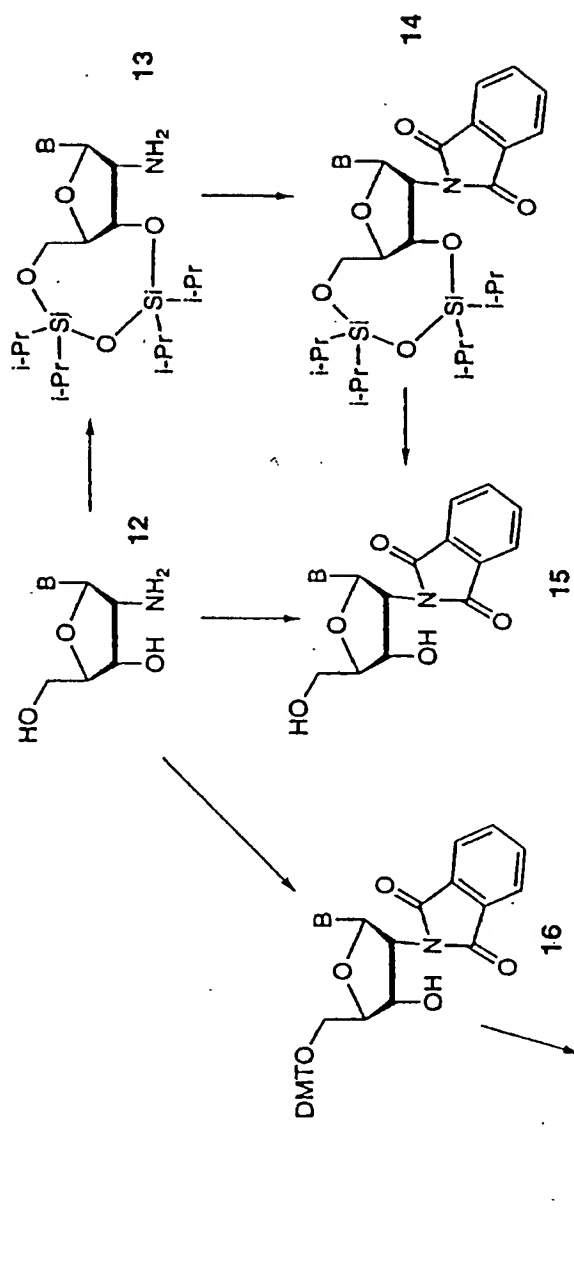


FIG. 16.

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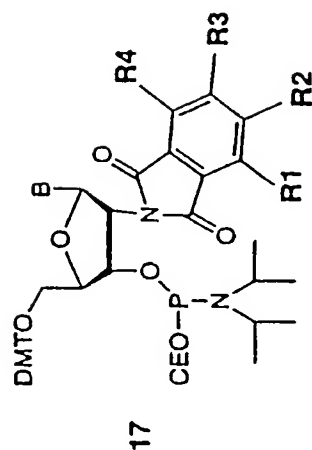
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B = any regular or modified base or abasic  
R1-R4 = alkyl or halogen

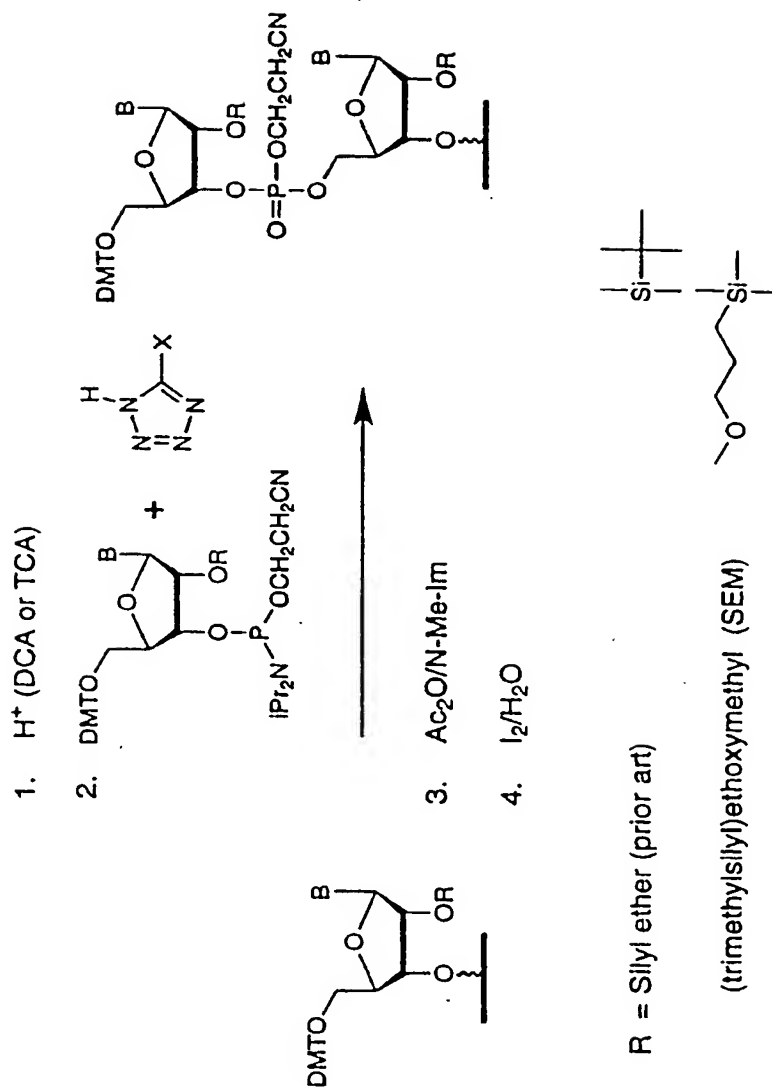
FIG. 17



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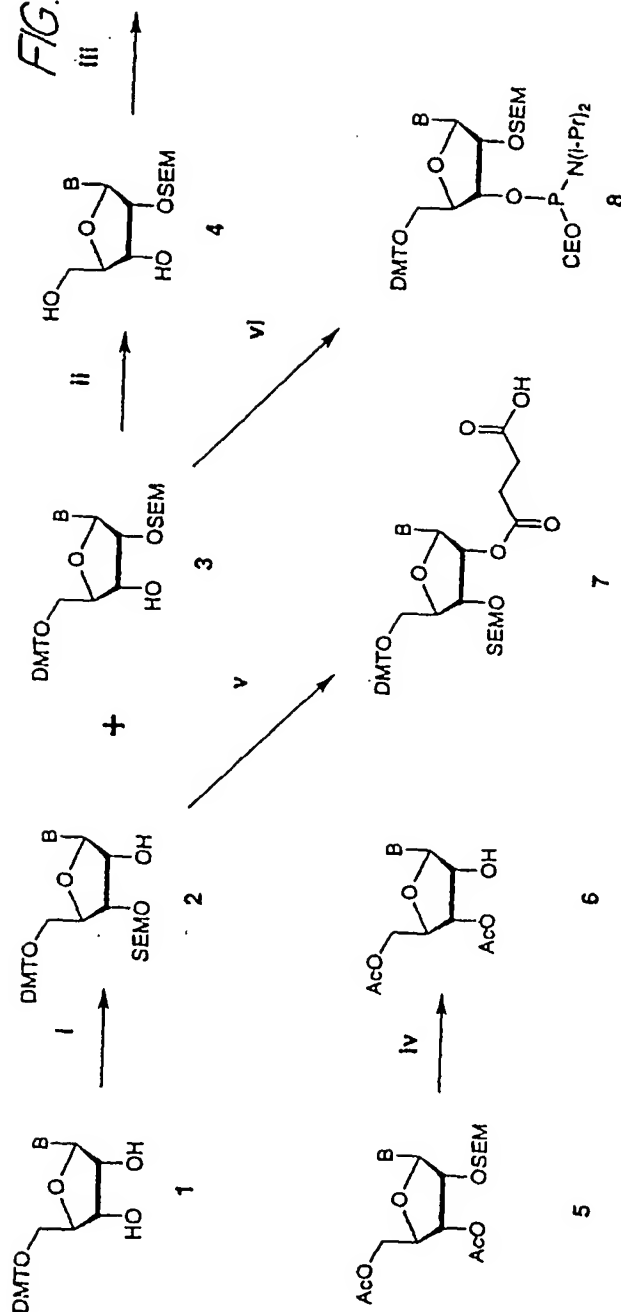
FIG. 18.





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FIG. 19.



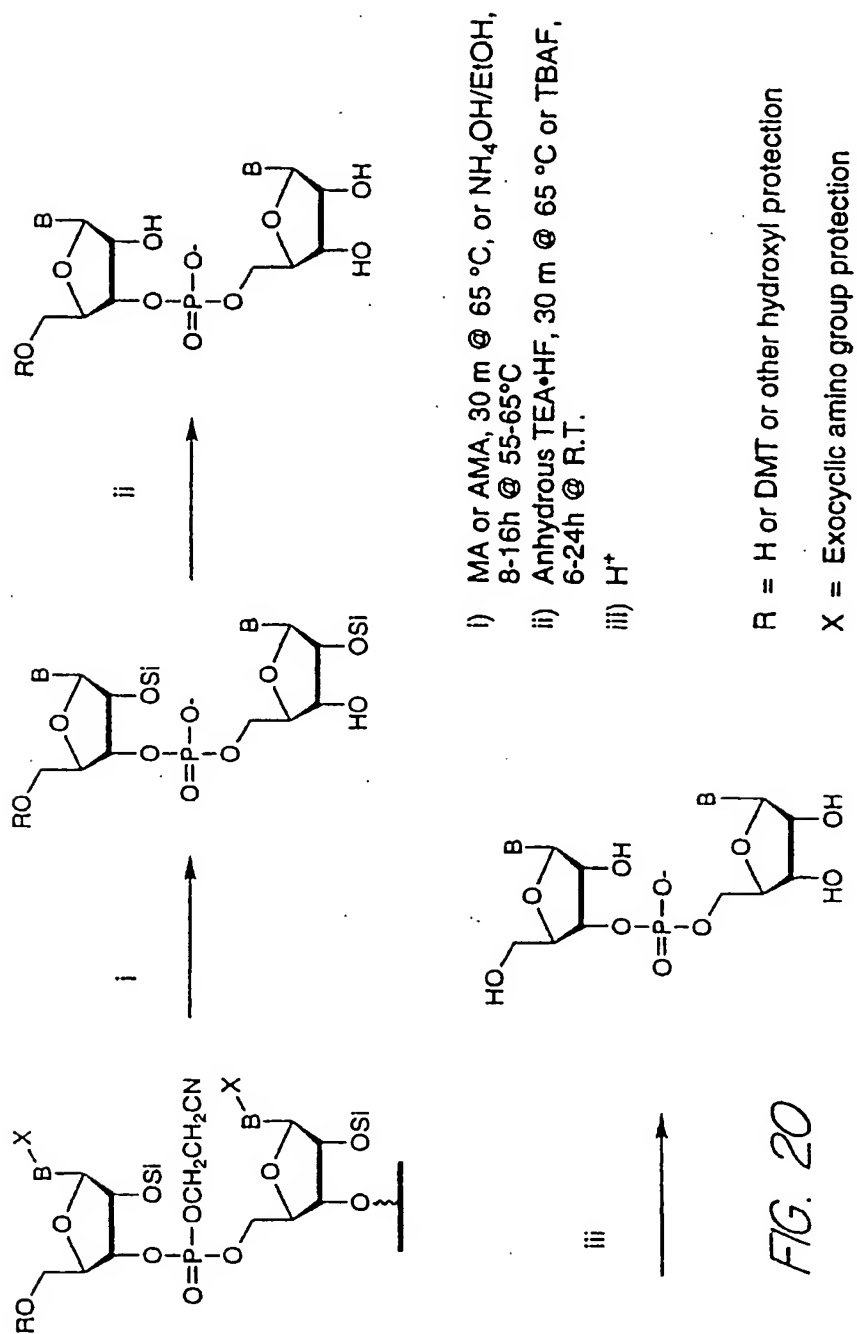
i) =  $\text{SnBu}_2\text{O}/\text{SEM-Cl}$   
 ii) =  $\text{H}^+$   
 iii) =  $\text{Ac}_2\text{O}$   
 iv) =  $\text{BF}_3 \cdot \text{OEt}_2$   
 v) = Succinic Anhydride  
 vi) =  $\text{P}(\text{OCE})(\text{N-Pr}_2)\text{Cl}$

B = Protected A, C, G, U, T, 2AP, I, DIAP, P etc.

SEM = (trimethylsilyl)ethoxymethyl/

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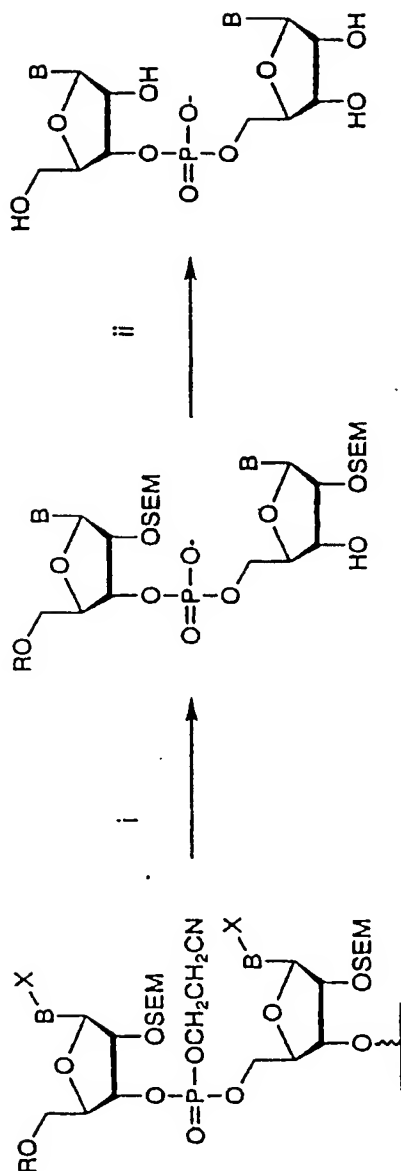


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FIG. 21.



i) MA or AMA, 30 m @ 65 °C or NH<sub>4</sub>OH or NH<sub>4</sub>OH/EtOH, 8-16h @ 55-65°C

ii) BF<sub>3</sub>•OEt<sub>2</sub>

SEM = (trimethylsilyl)ethoxymethyl

R = H or DMT or other hydroxyl protection

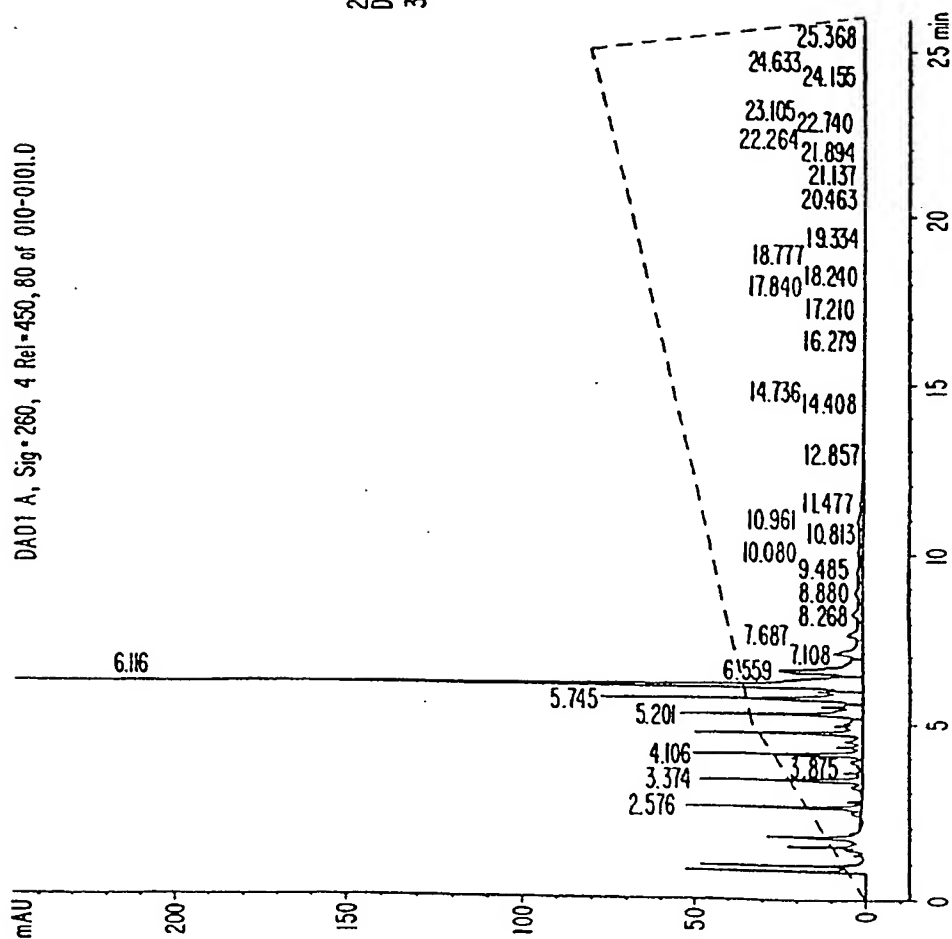
X = Exocyclic amino group protection

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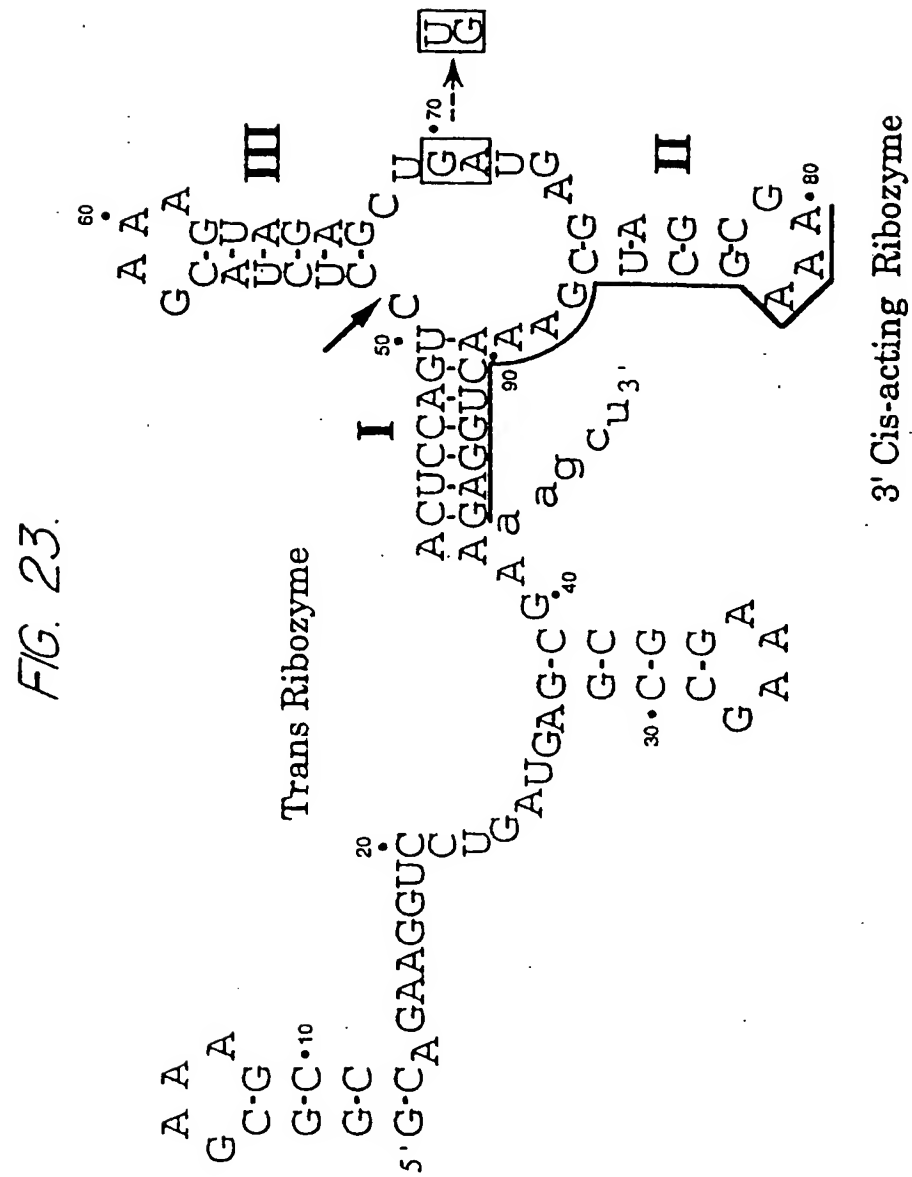
FIG. 22.  
2'-O-SEM PROTECTED U 10-mer  
DEPROTECTED WITH  $\text{BF}_3 \cdot \text{OEt}_2$   
30m, 3eq./nucleotide



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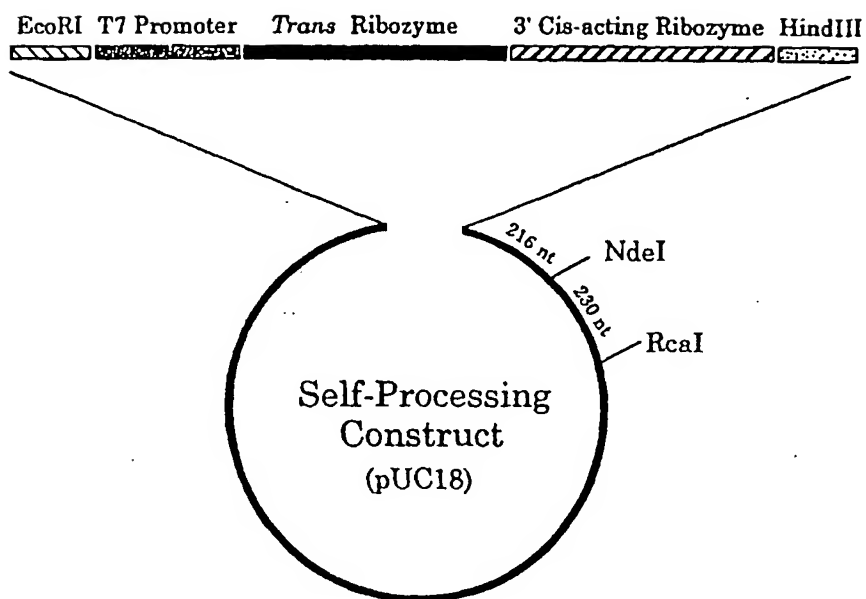


FIG. 25.

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FIG. 26.



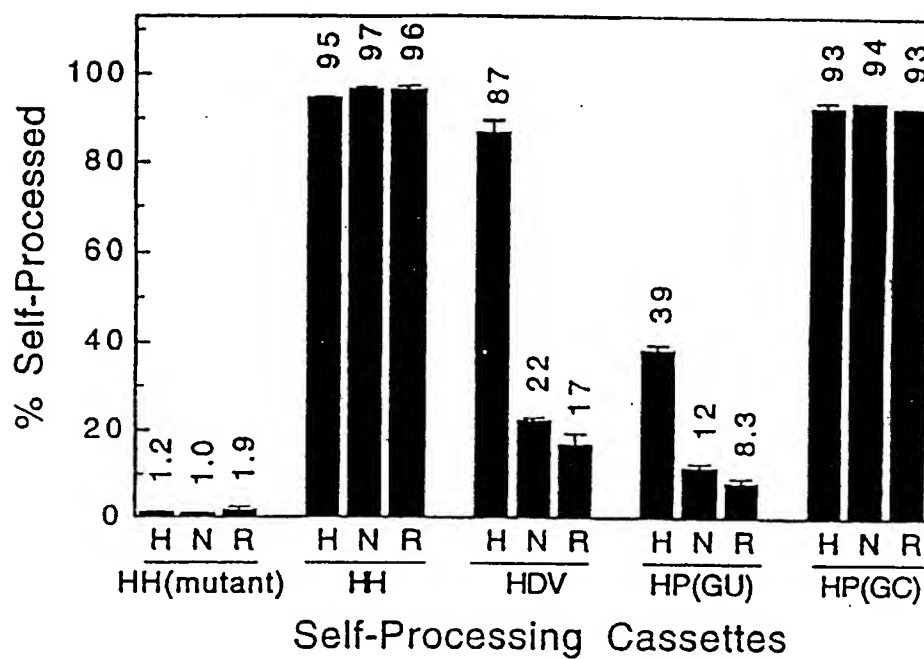
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FIG. 27.



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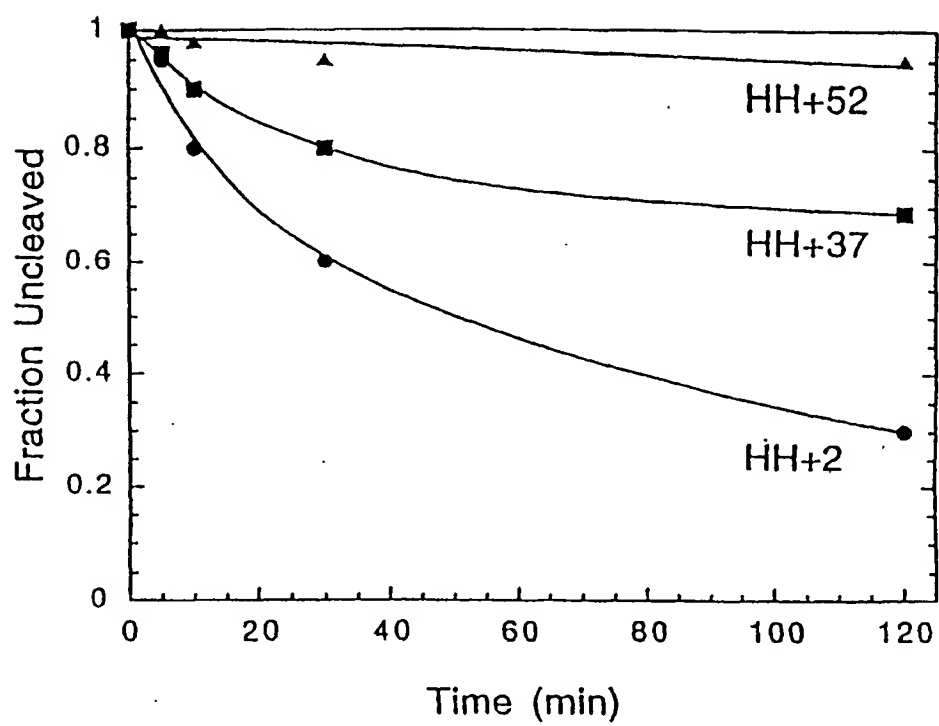


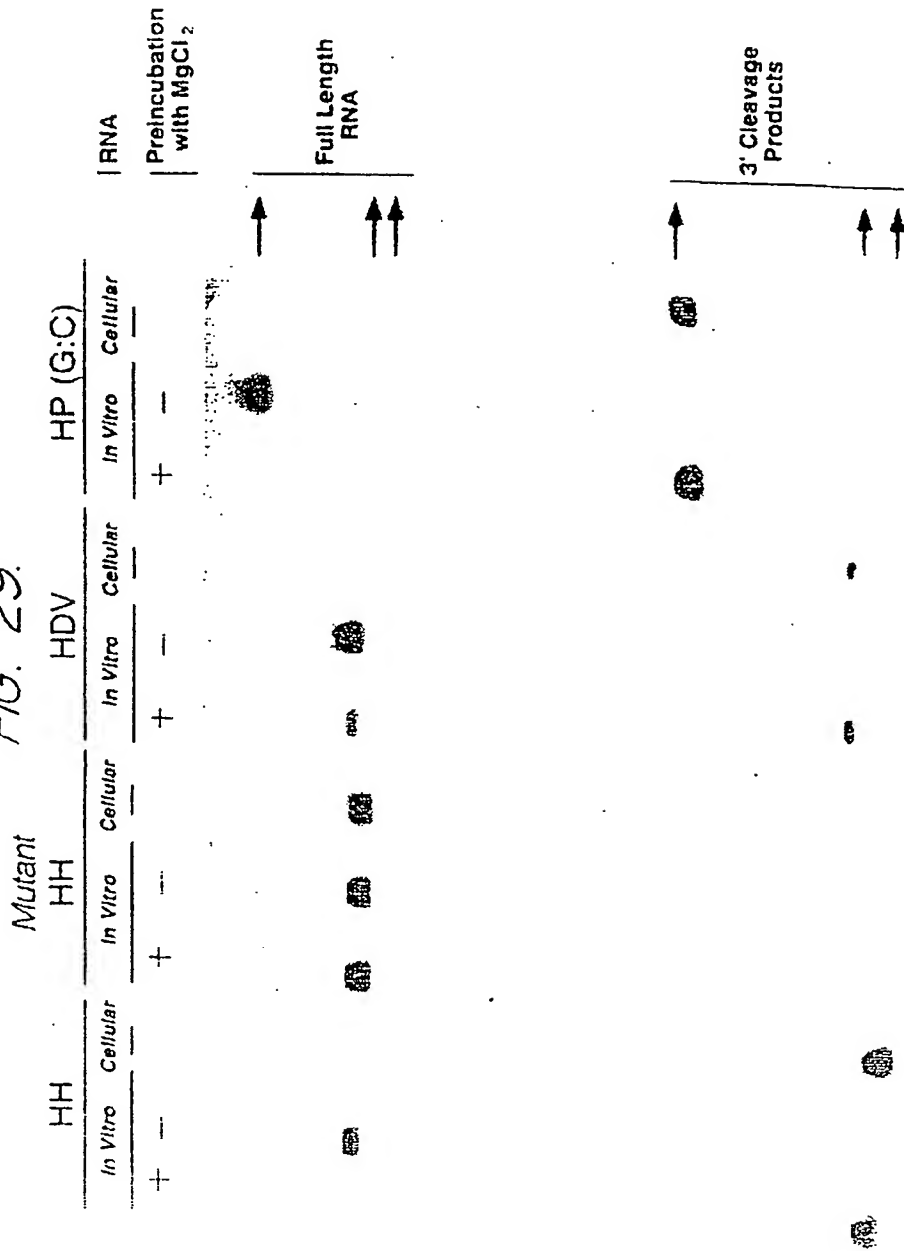
FIG. 28.

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FIG. 29.



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FIG. 30

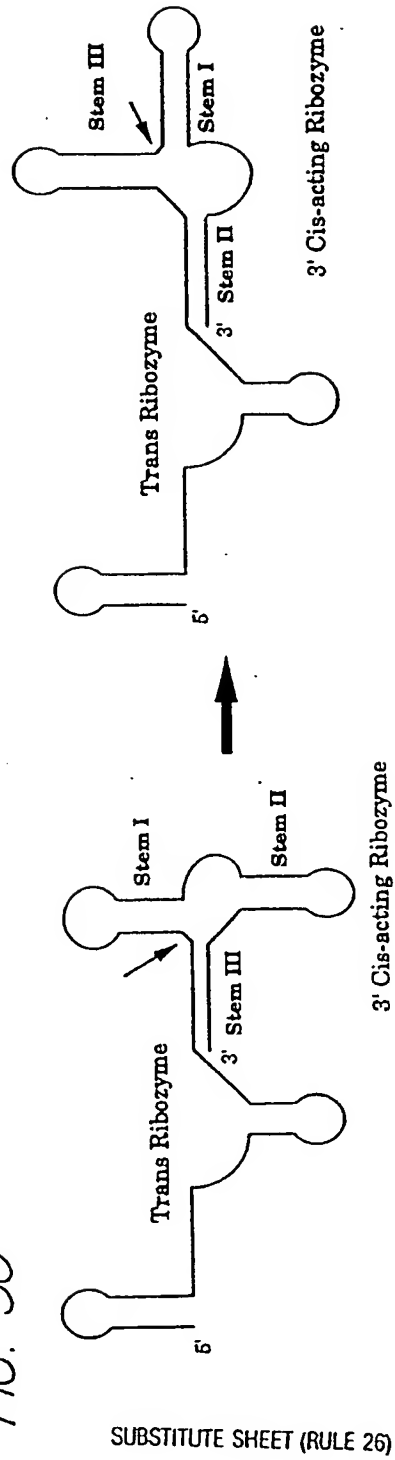
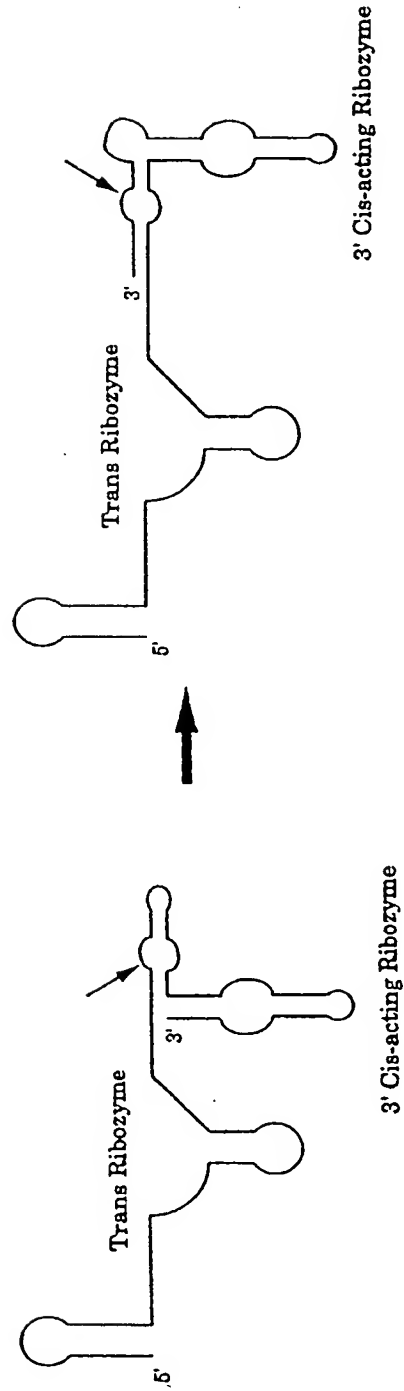


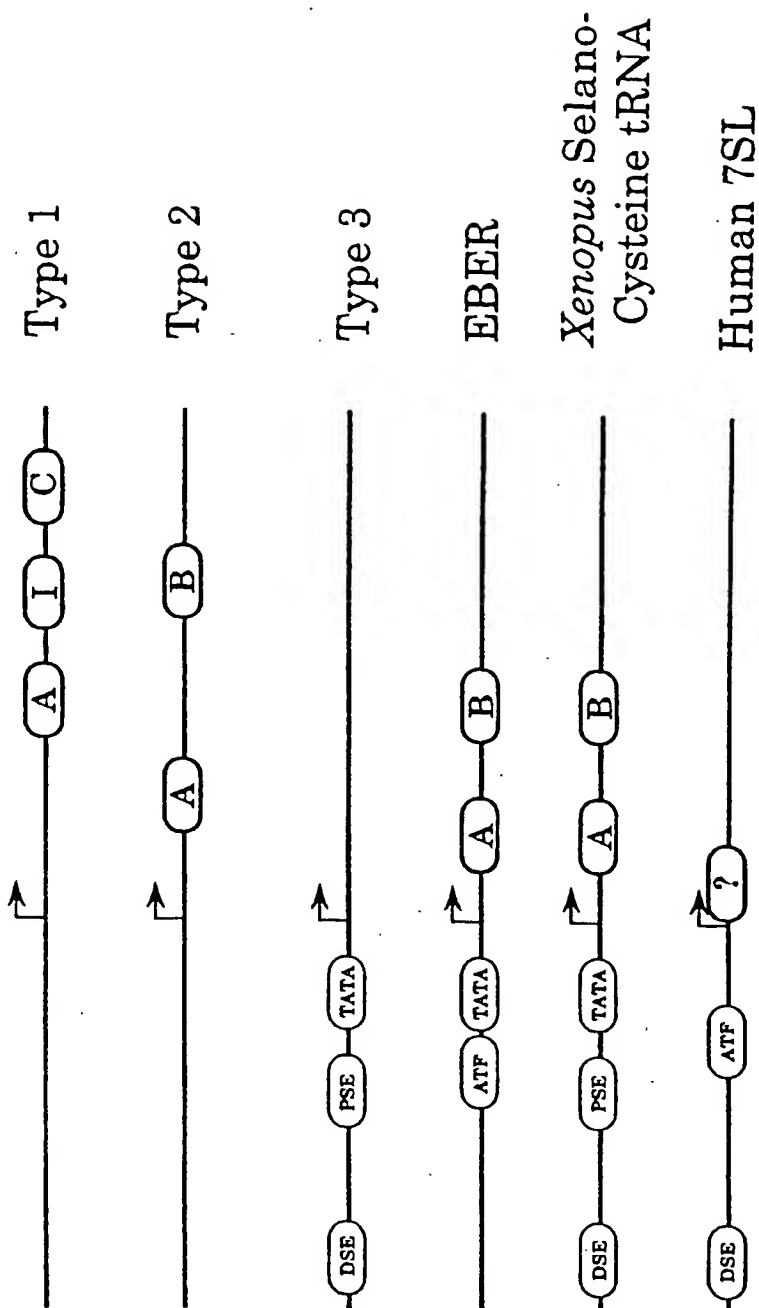
FIG. 31



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FIG. 32.



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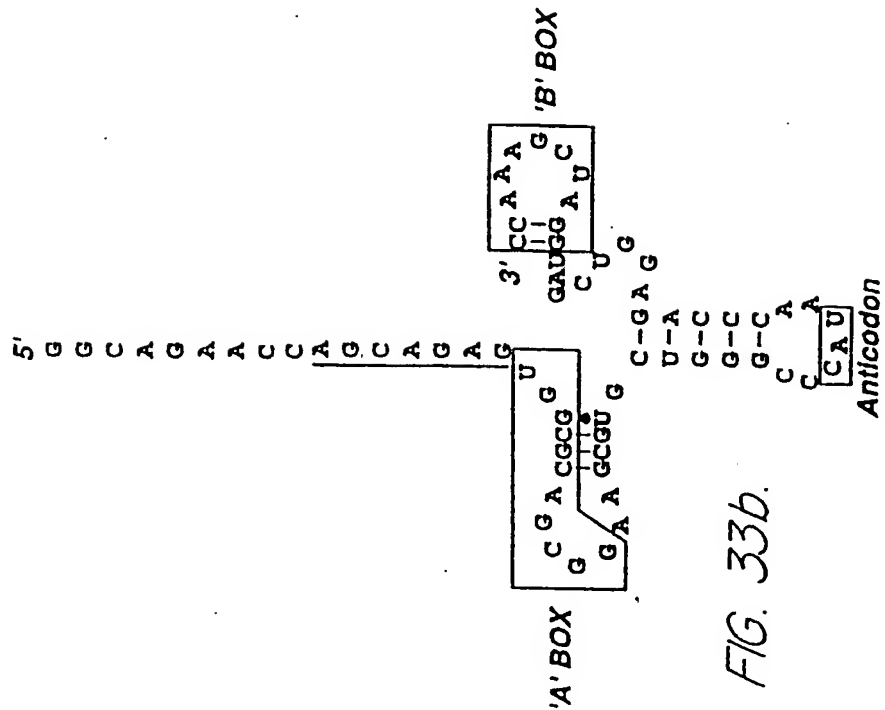


FIG. 33b.

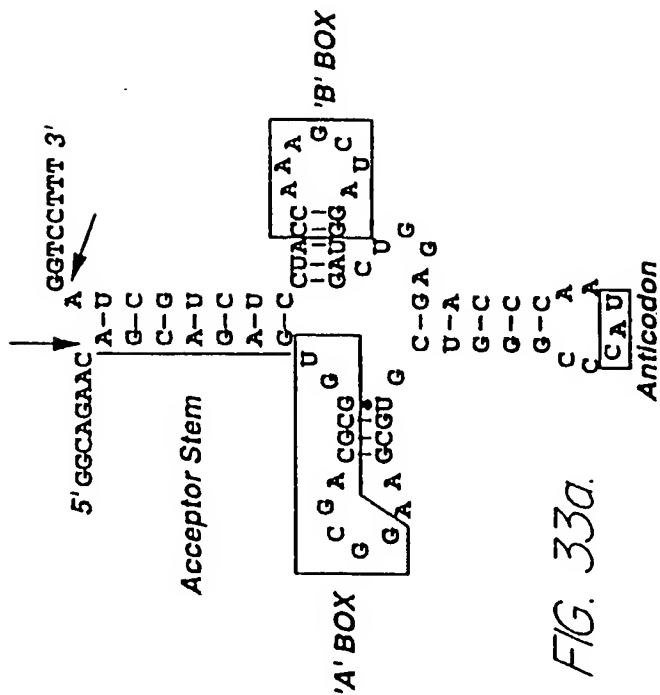


FIG. 33a.

met  
tRNA<sub>i</sub>

Δ 3-5

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FIG. 34a.

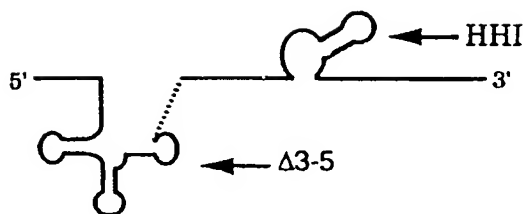
 $\Delta 3-5$ /HHI

FIG. 34b.

S3

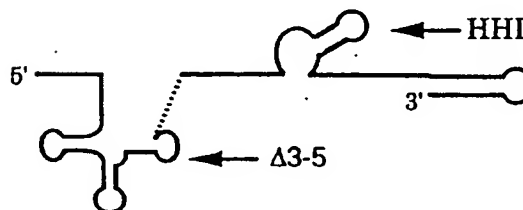


FIG. 34c.

S5

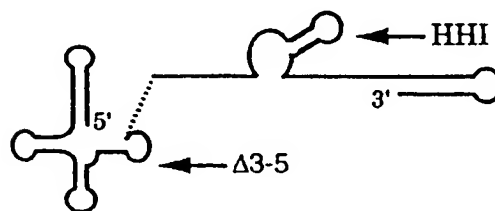


FIG. 34d.

S35

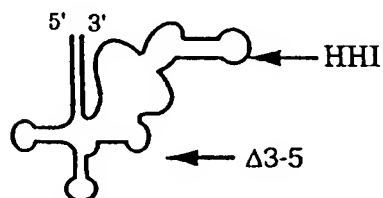
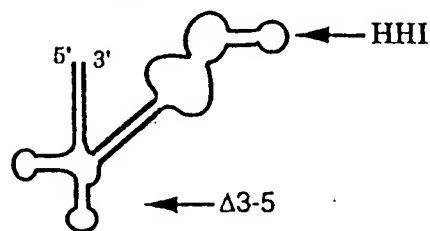


FIG. 34e.

S35Plus



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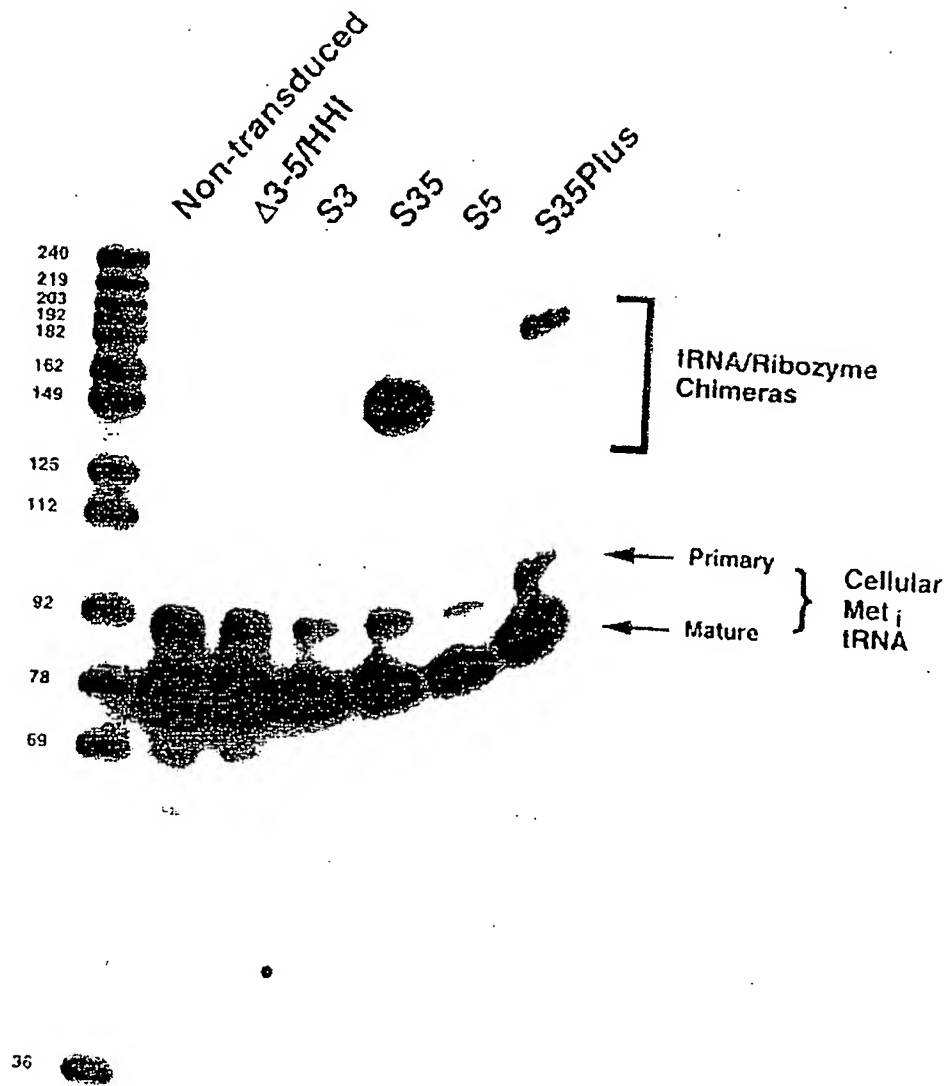


FIG. 35.

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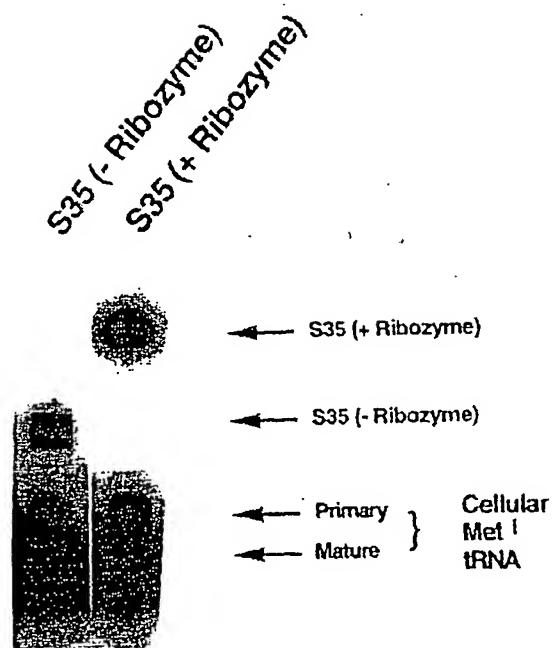


FIG. 36.

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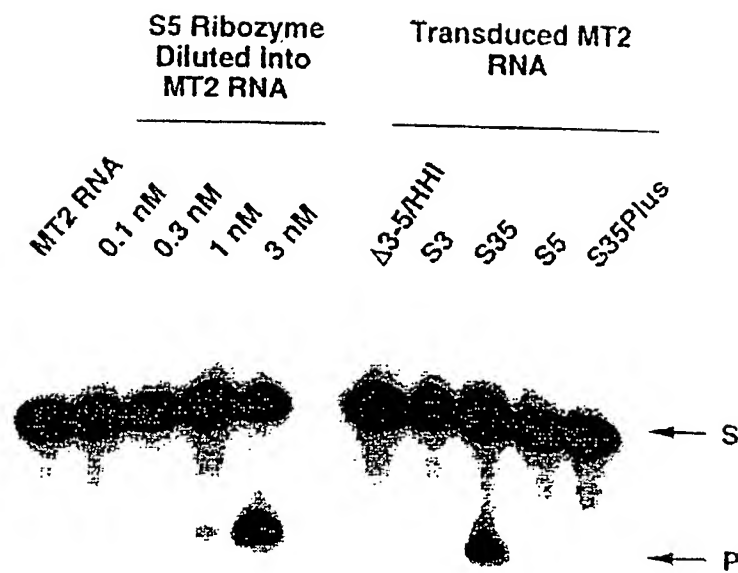


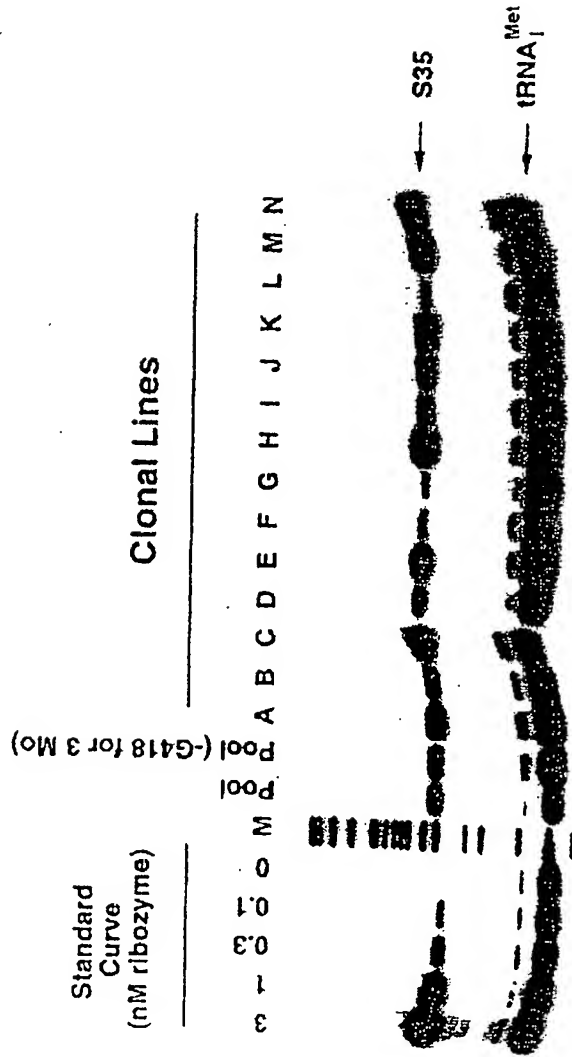
FIG. 37.

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FIG. 38

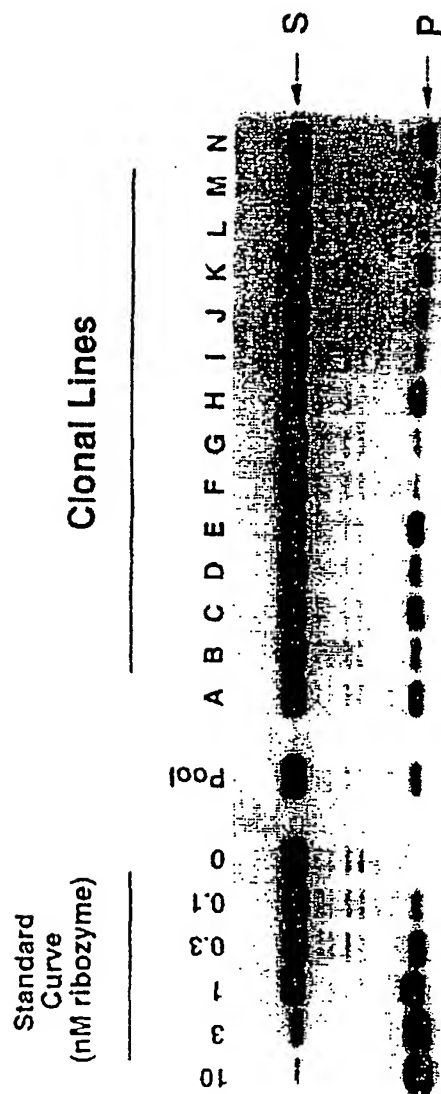


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FIG. 39.



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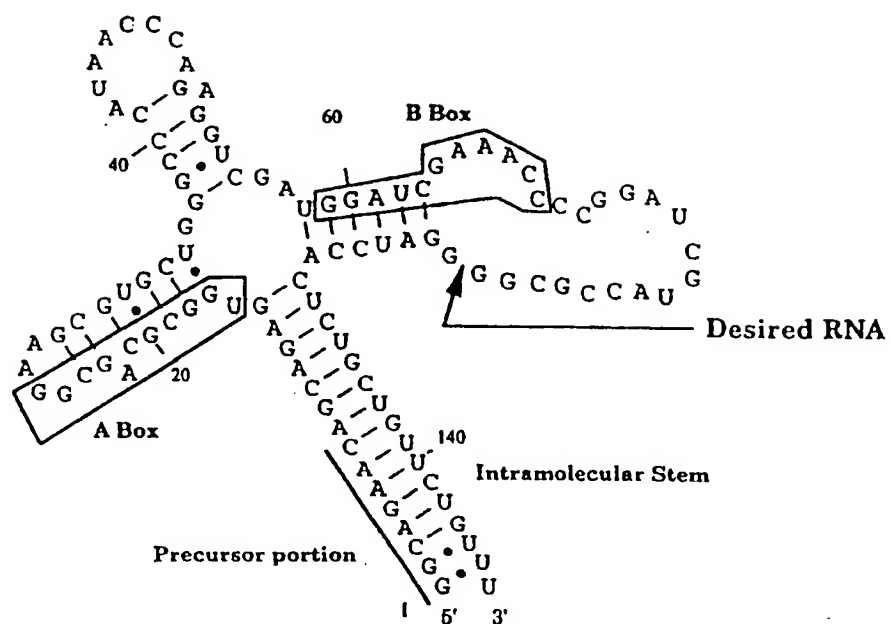


FIG. 40.

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FIG. 41.

Desired RNA

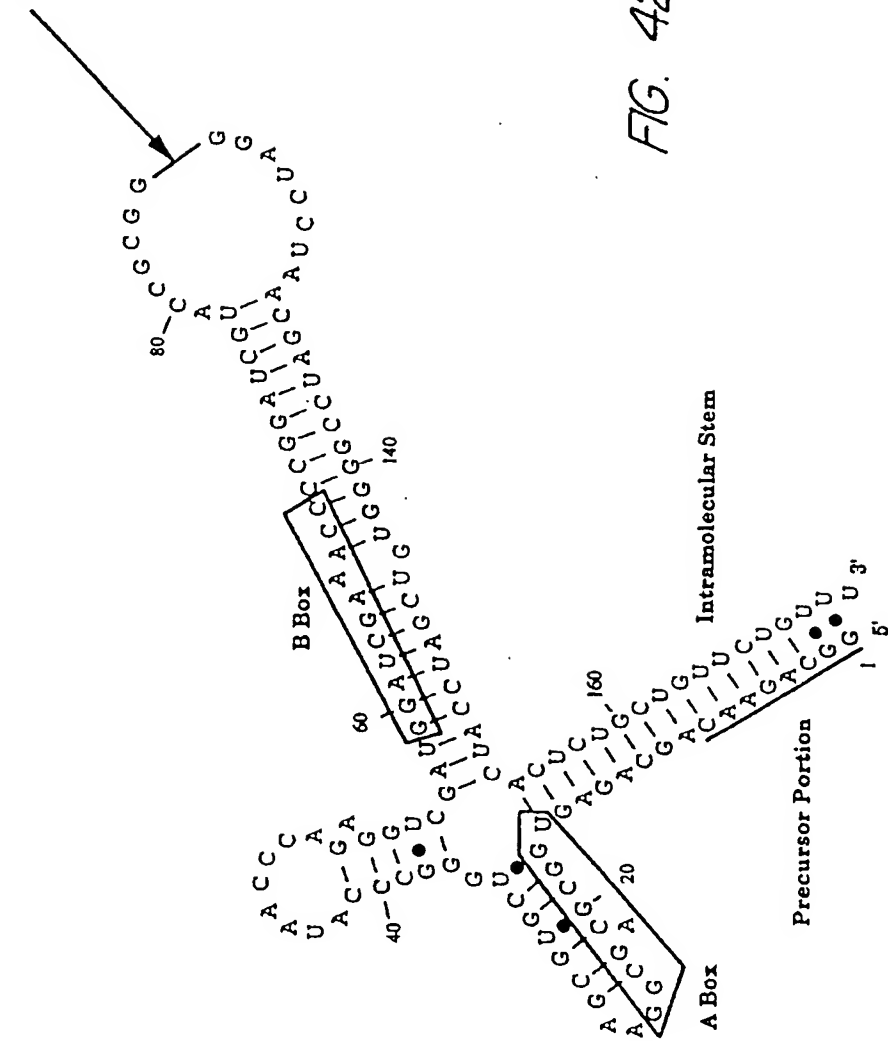


FIG. 42.

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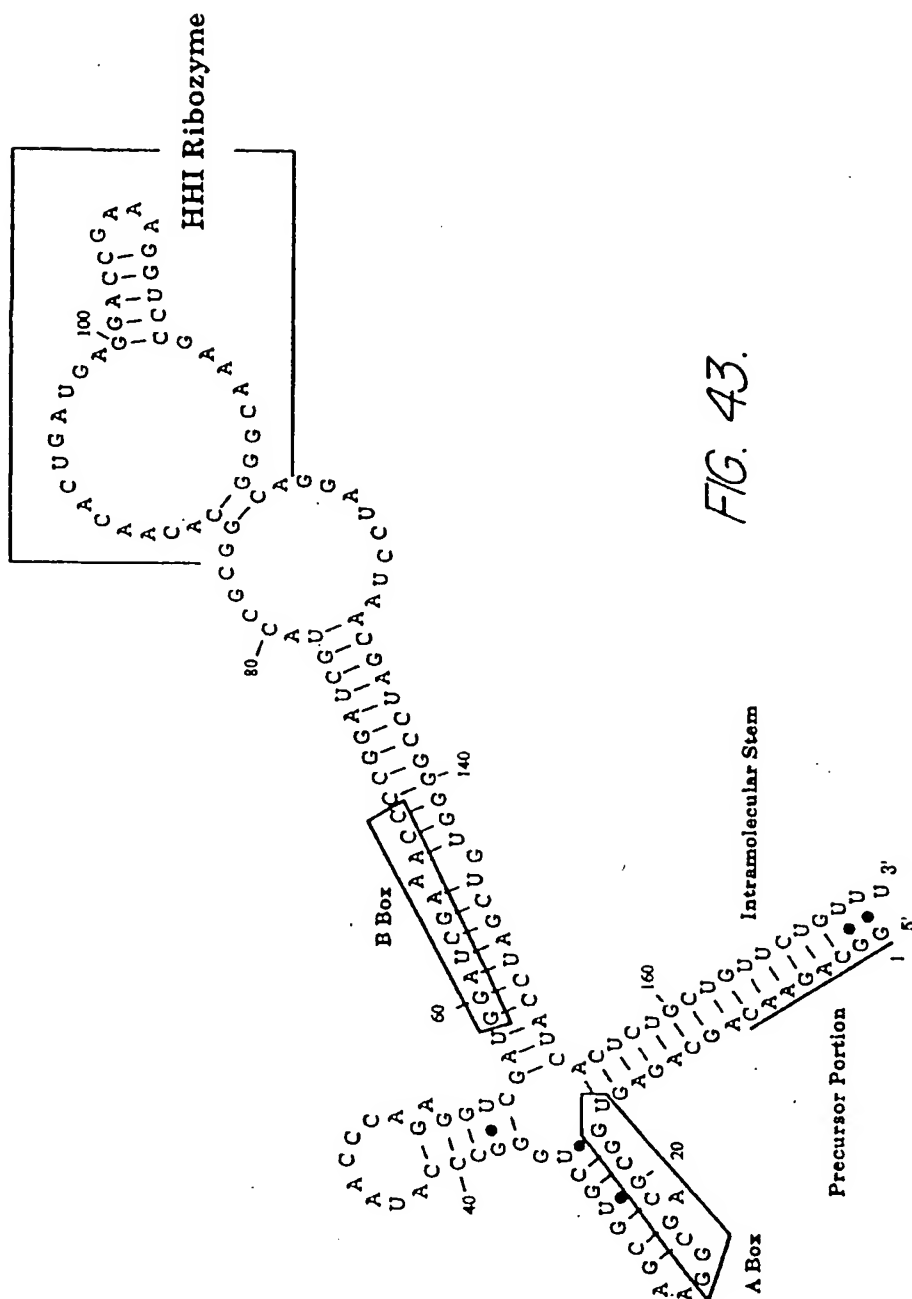


FIG. 43.

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*FIG. 44.***S35 Sequence**

GGCAGAACAG CAGAGUGGCG CAGCGGAAGC GUGCUGGGCC CAUAACCCAG 50  
 AGGUCGAUGG AUCGAAACCC CGGAUCGUAC CGCGGUGGAU CCACUCUGCU 100  
 GUUCUGUUU 109

*FIG. 45.***HHIS35**

GGCAGAACAG CAGAGUGGCG CAGCGGAAGC GUGCUGGGCC CAUAACCCAG 50  
 AGGUCGAUGG AUCGAAACCC CGGAUCGUAC CGCGGCACAA CACUGAUGAG 100  
GACCGAAAGG UCCGAAACGG GCAGGAUCCA CUCUGCUGUU CUGUUU 146

Underlined bases indicate the HHI ribozyme sequence

*FIG. 46.***S35 Plus Sequence**

GGCAGAACAG CAGAGUGGCG CAGCGGAAGC GUGCUGGGCC CAUAACCCAG 50  
 AGGUCGAUGG AUCGAAACCC CGGAUCGUAC CGCGGGGAUC CUAACGAUCC 100  
 GGGGUGUCGA UCCAUCACUC UGCUGUUCUG UU U 133

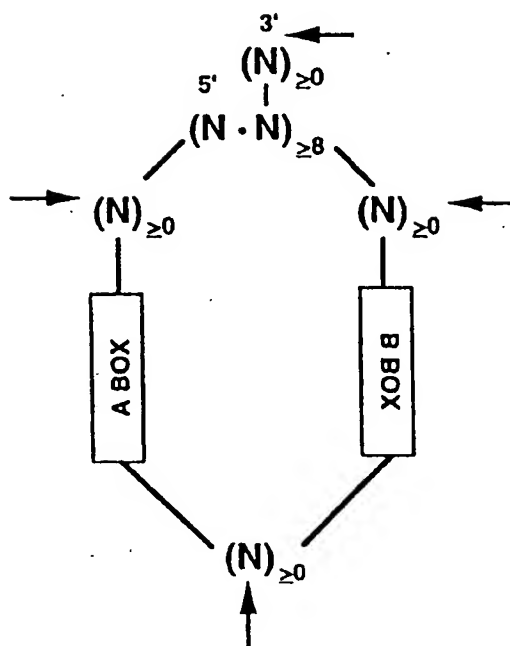
*FIG. 47.***HHIS35 Plus**

GGCAGAACAG CAGAGUGGCG CAGCGGAAGC GUGCUGGGCC CAUAACCCAG 50  
 AGGUCGAUGG AUCGAAACCC CGGAUCGUAC CGCGGCACAA CACUGAUGAG 100  
GACCGAAAGG UCCGAAACGG GCAGGAUCCU AACGAUCCGG GGUGUCGAUC 150  
 CAUCACUCUG CUGUUCUGUU U 171

Underlined bases indicate the HHI ribozyme sequence  
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FIG. 48.



A BOX = URGNNAGYGG

B BOX = GGUUCGANUCC

This is based on Geiduschek & Tocchini-Valentini, (1988) *Annu. Review Biochem.* 57, 873-914. However this consensus sequence is not meant to be limiting

N = A, U, G, or C

R = Purine

Y = Pyrimidine

• = Indicates base-pairing

— = Indicates covalent linkage

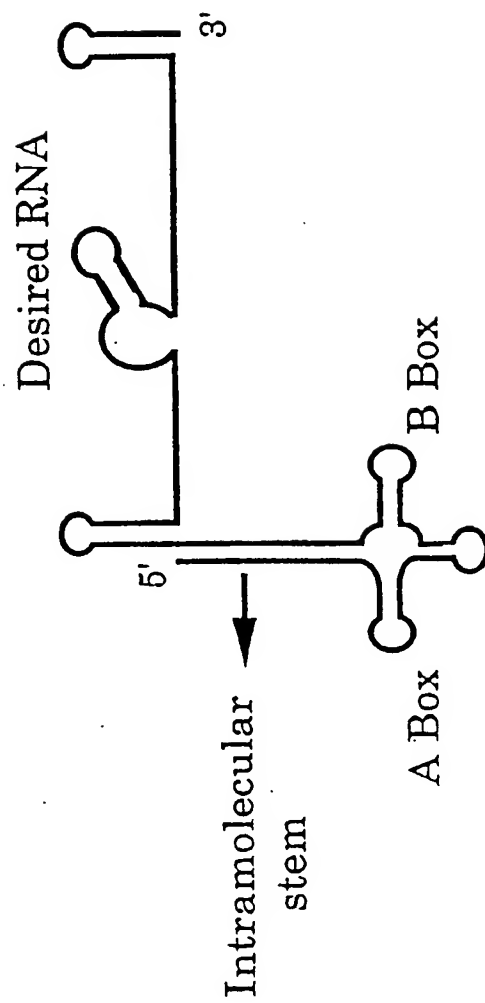
→ = Indicates sites at which desired RNAs can be cloned

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FIG. 49.



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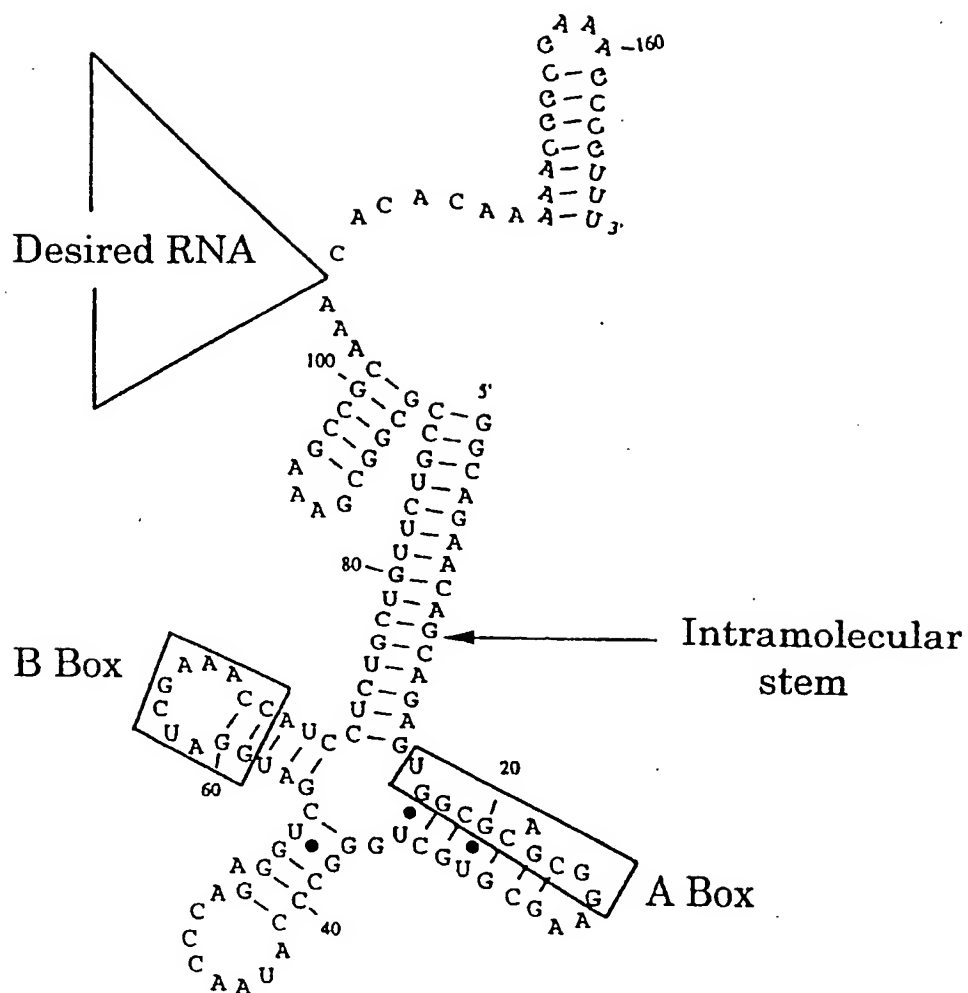


FIG. 50.

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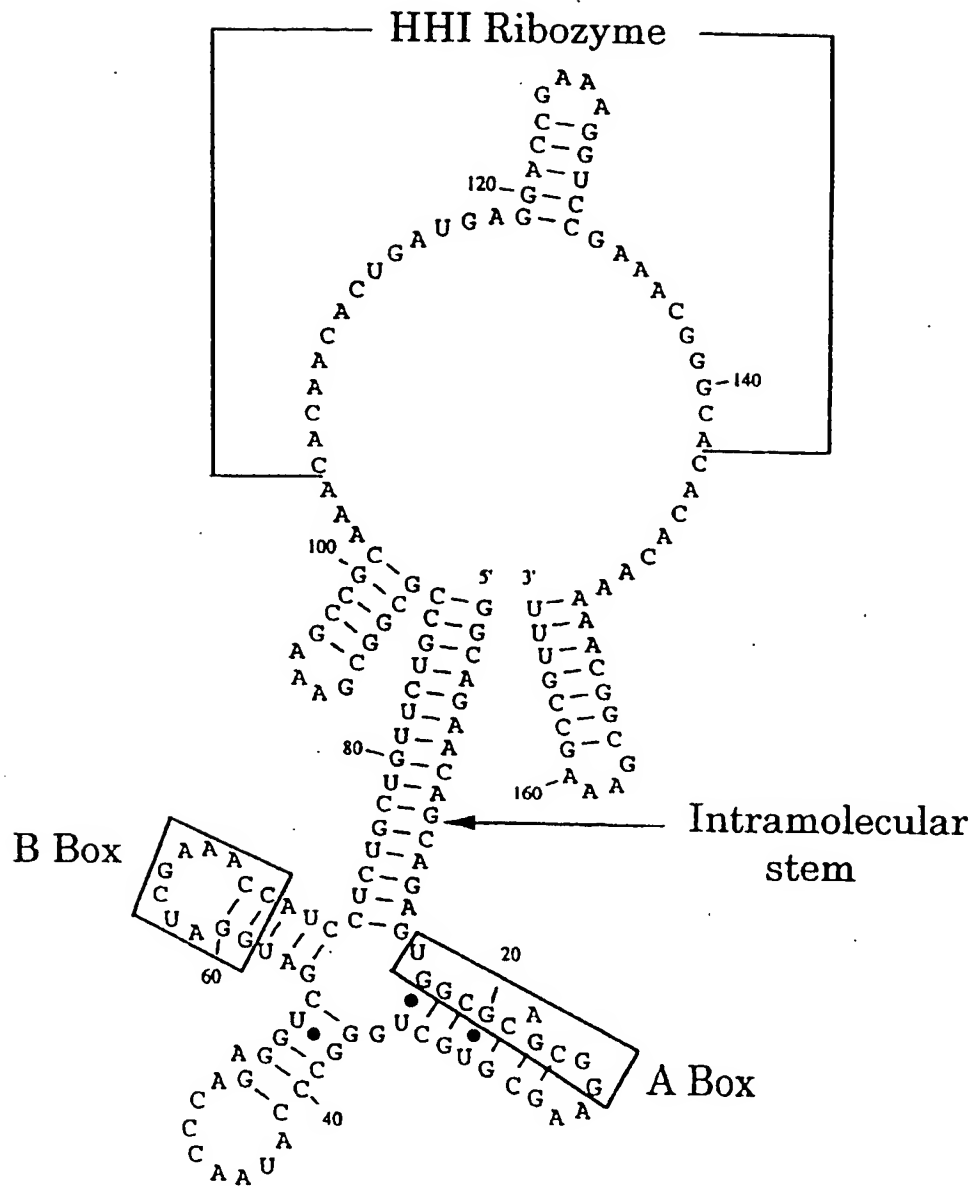


FIG. 51.

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FIG. 52a.

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A: TRZ-A

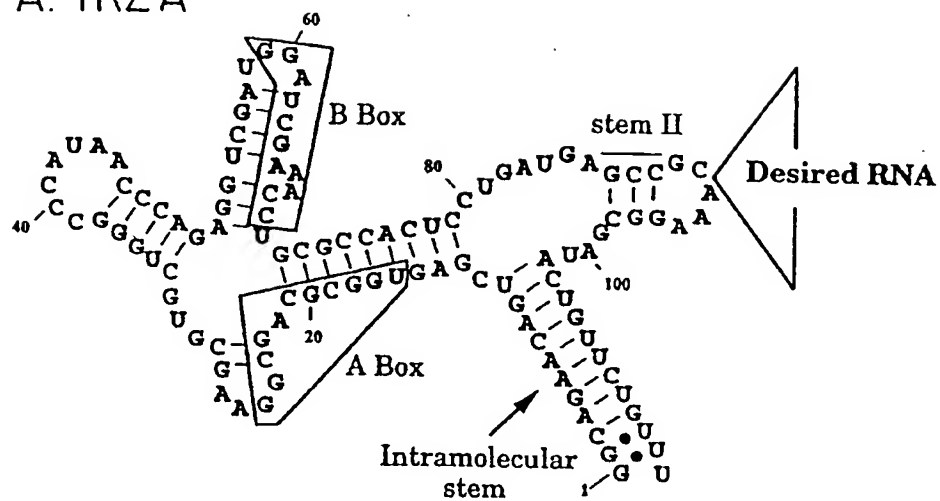
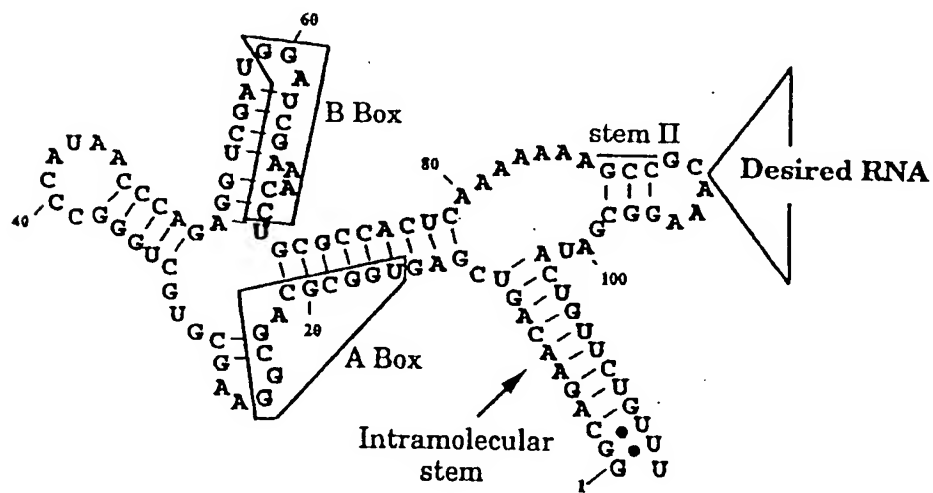
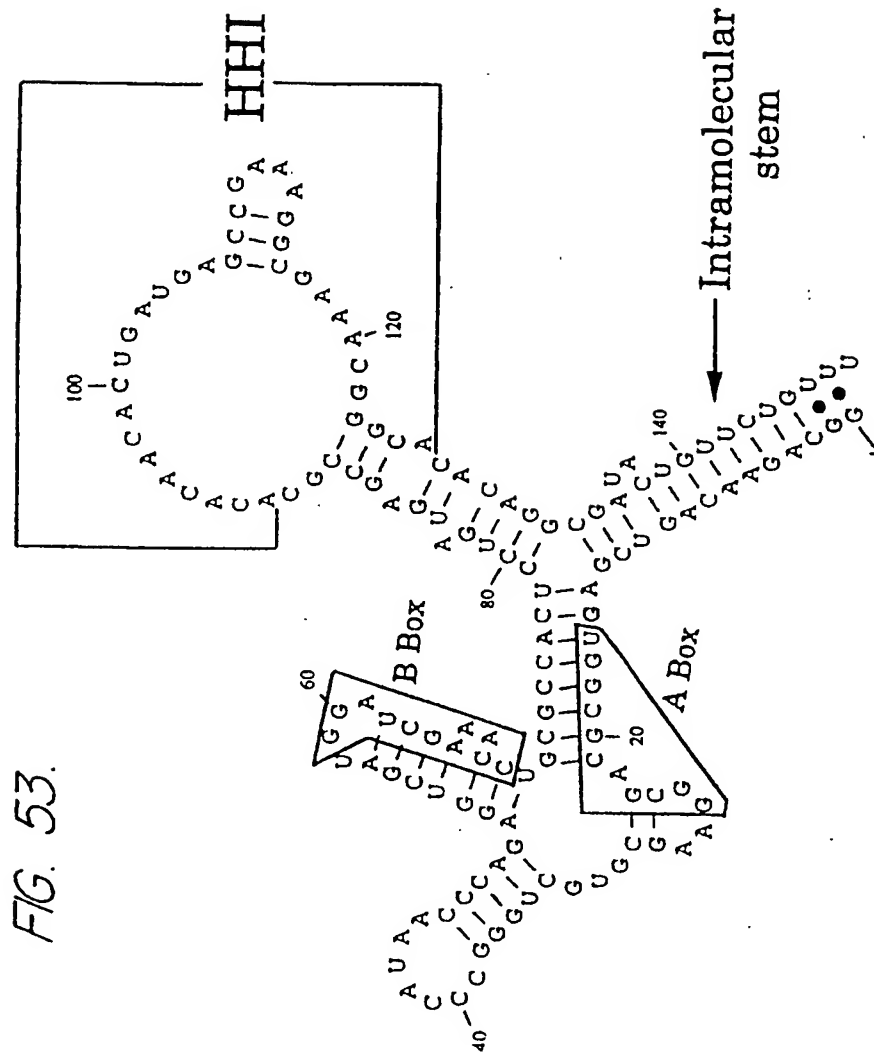


FIG. 52b.

B: TRZ-B



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FIG. 54.



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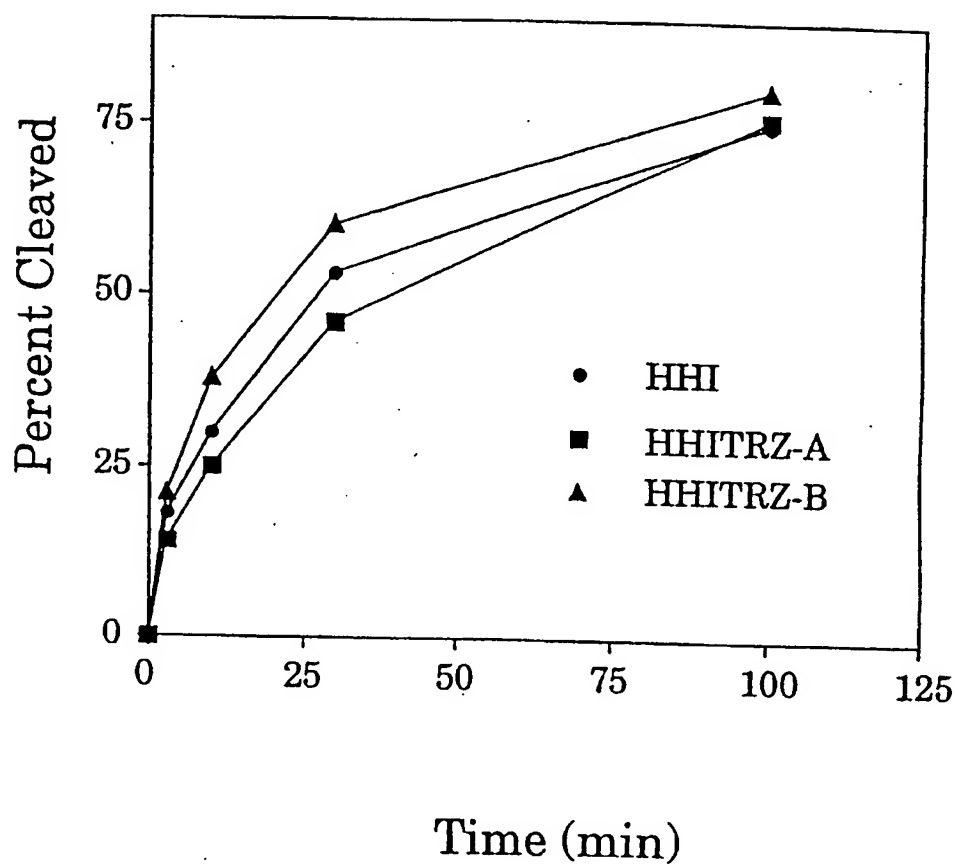


FIG. 55.

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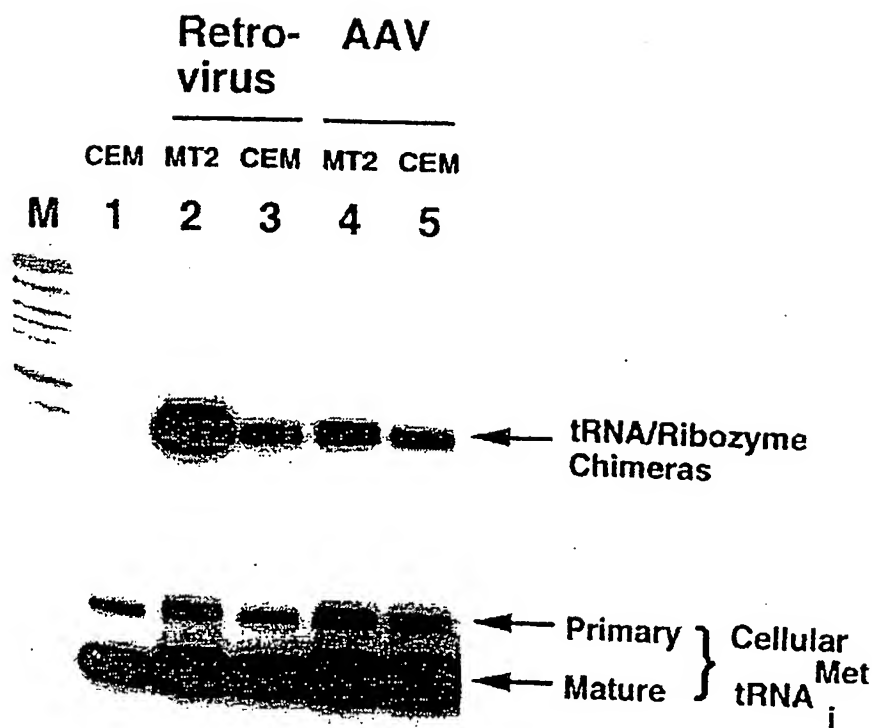


FIG. 56.

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FIG. 57a.

AAV Vector

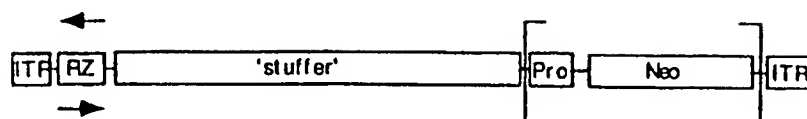
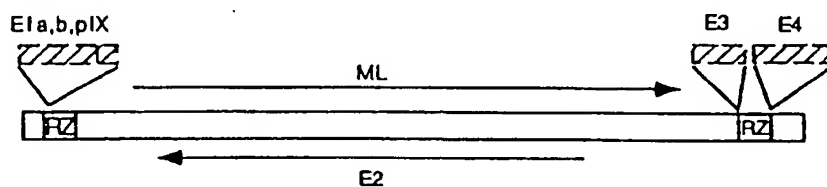


FIG. 57b.

Adenovirus Vector



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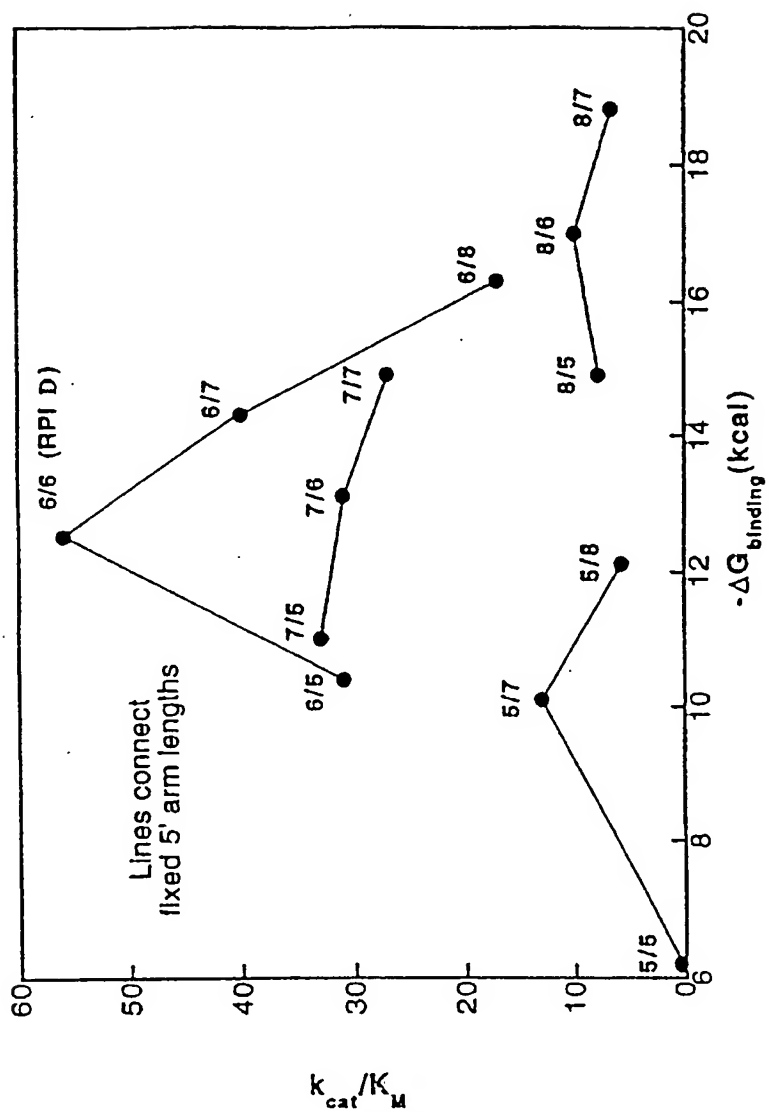
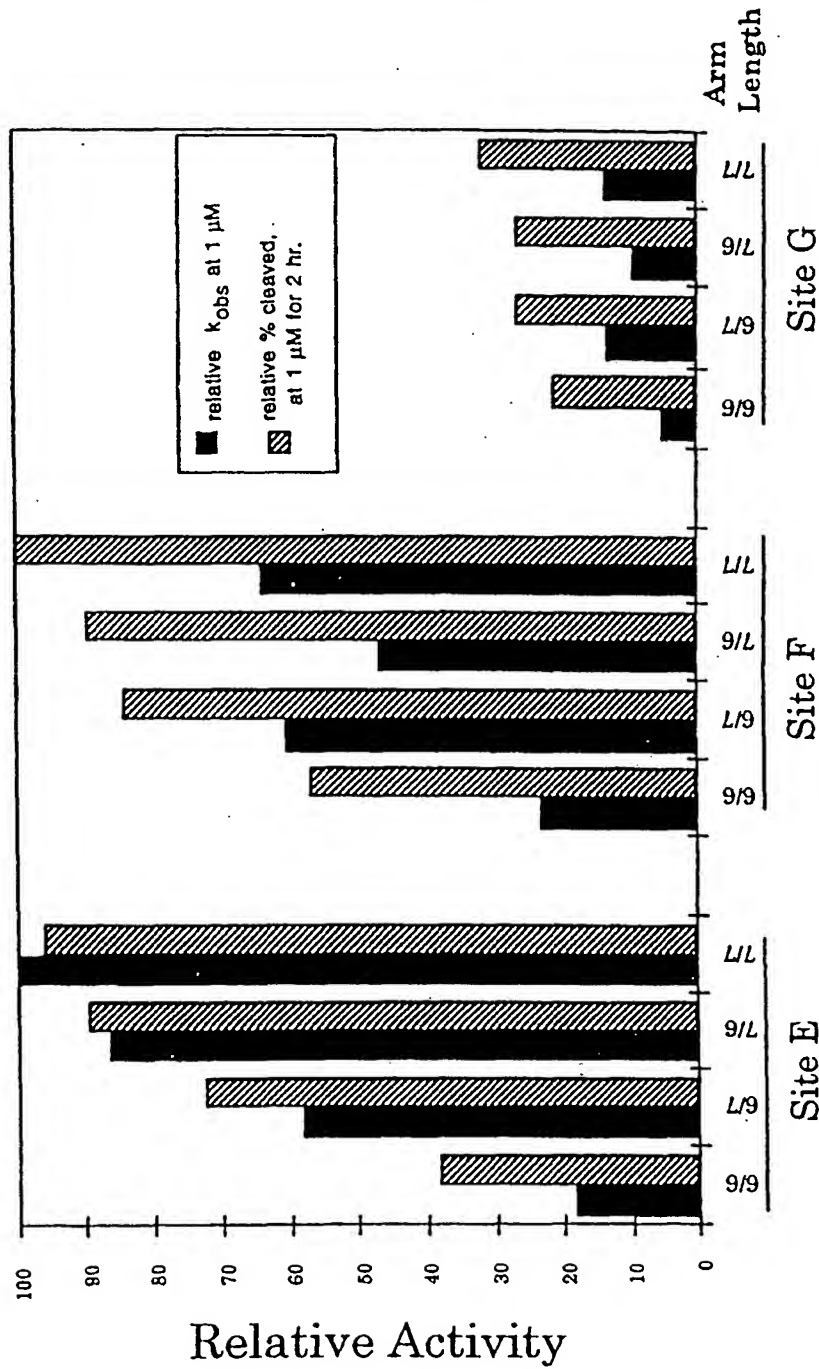


FIG. 58.

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Ribozyme

FIG. 59.

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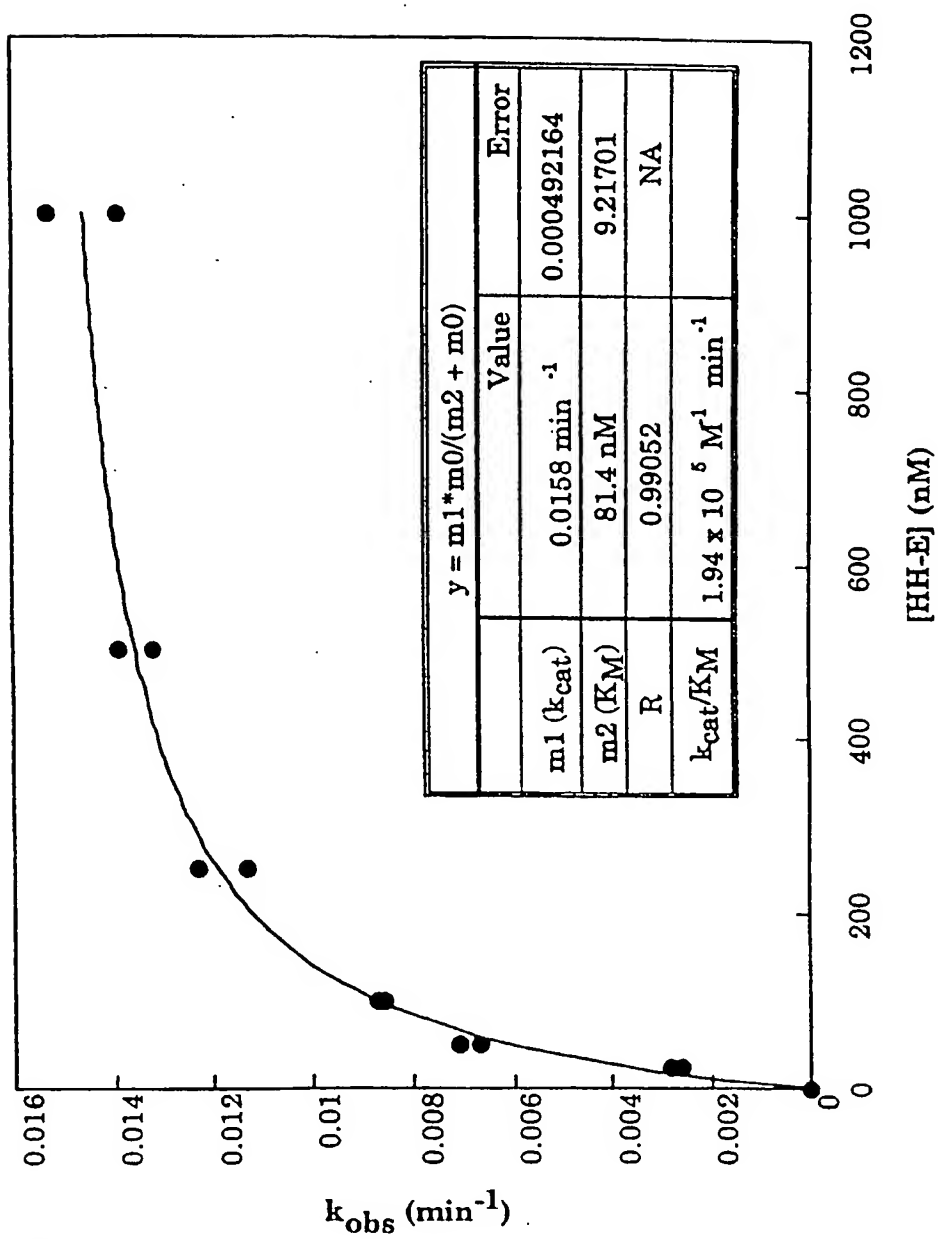
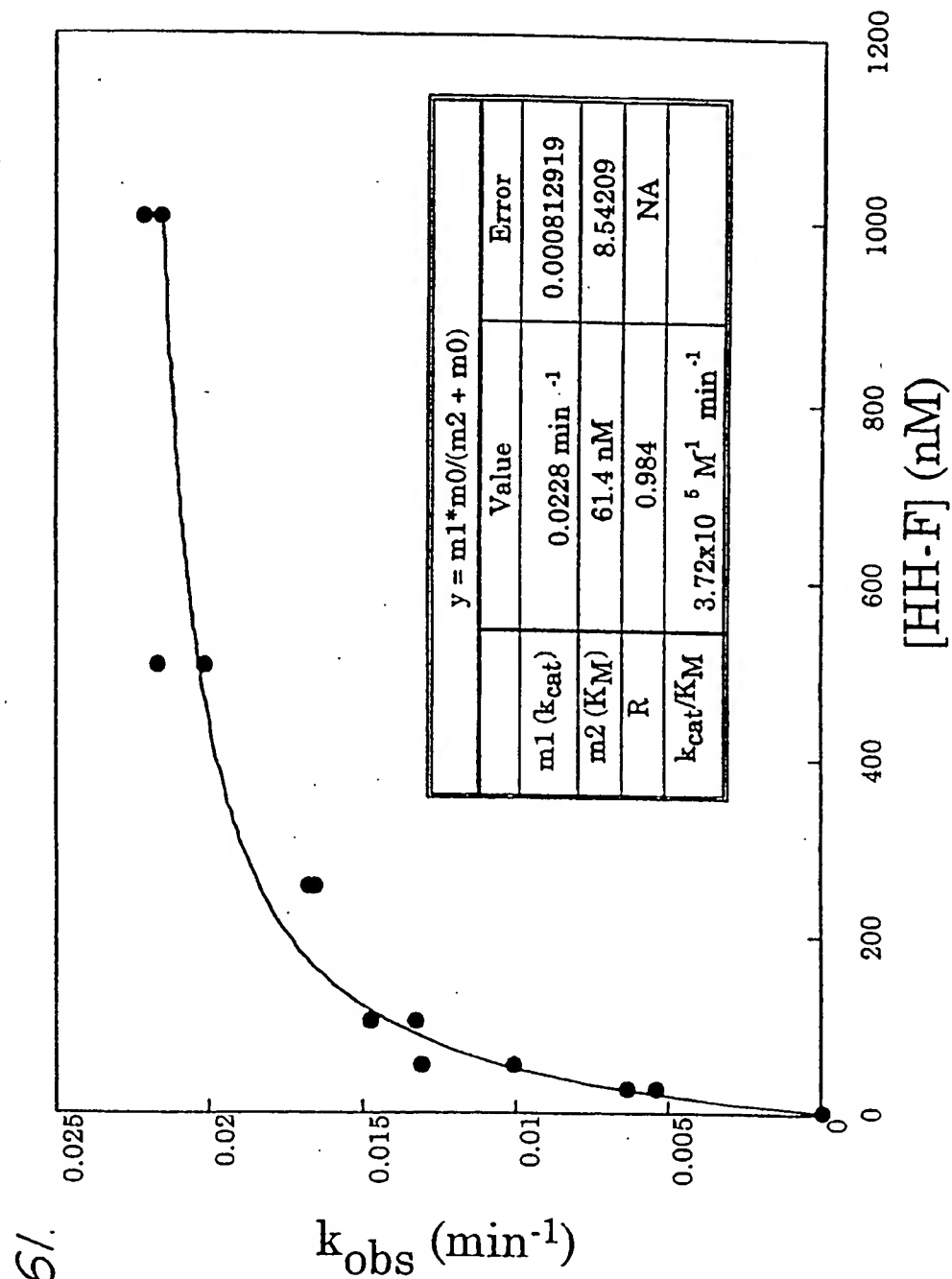


FIG. 60.

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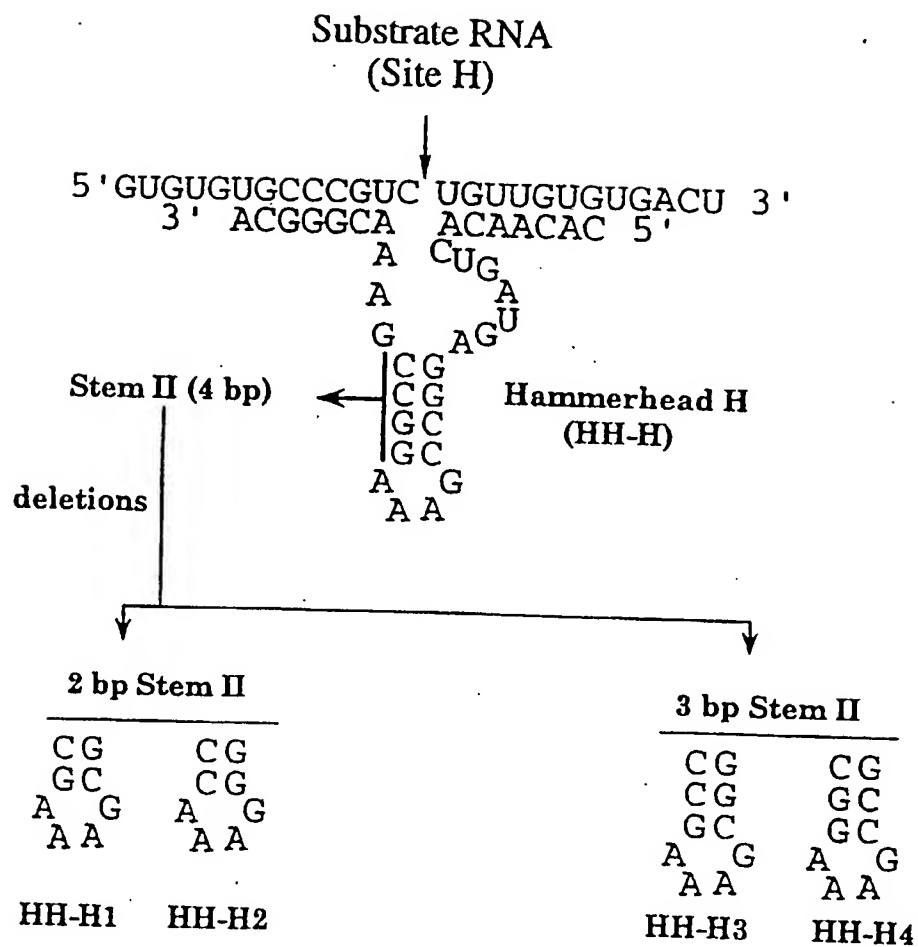


FIG. 62.



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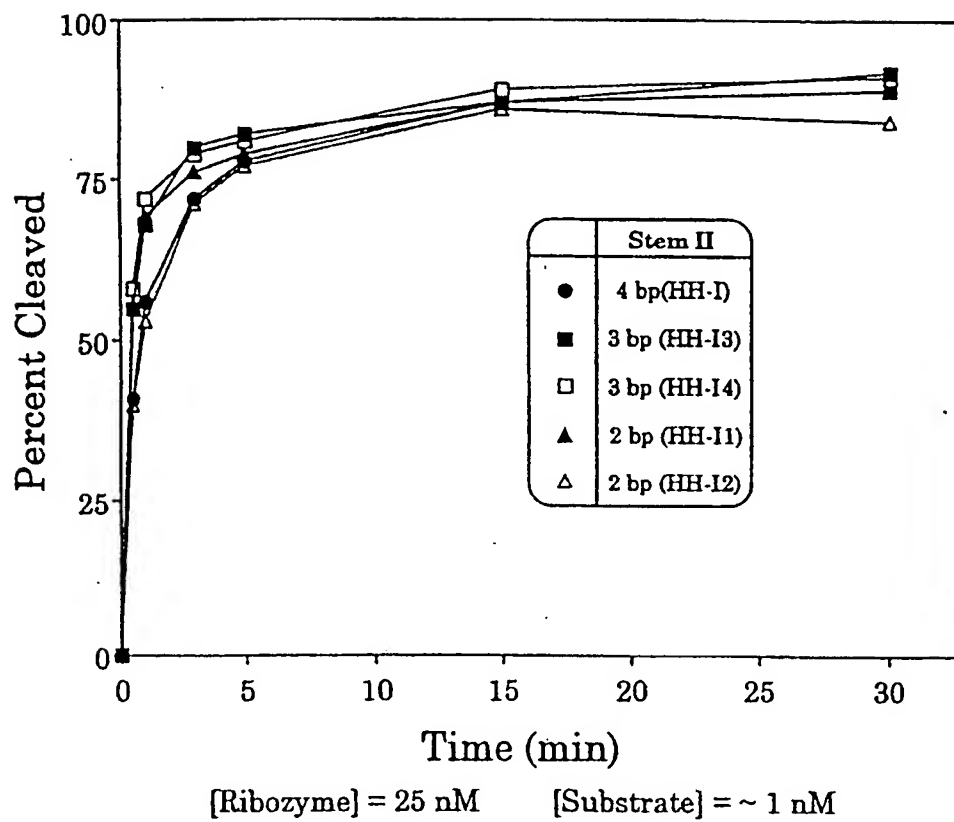


FIG. 63.

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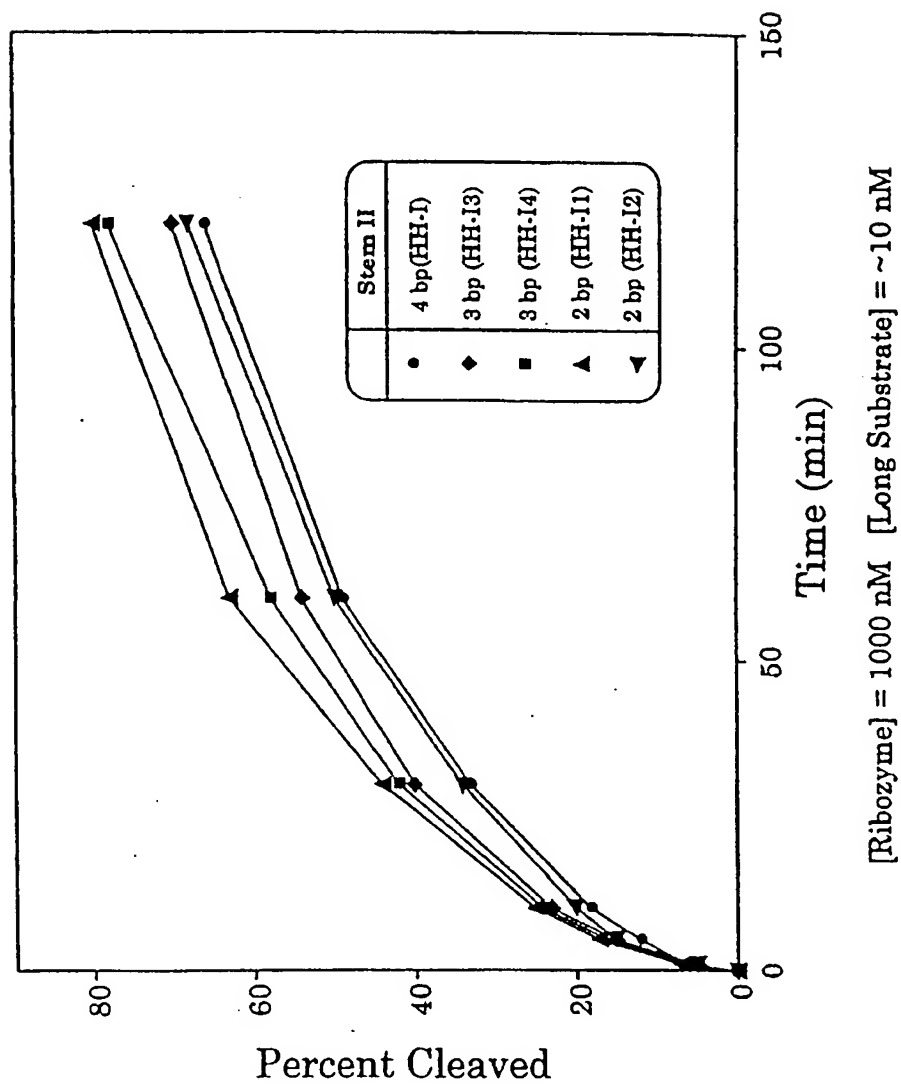


FIG. 64.

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FIG. 65b.

Substrate RNA (site J)

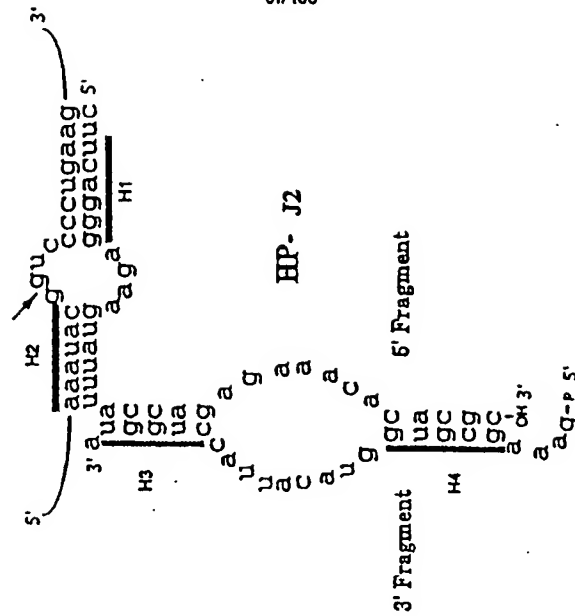
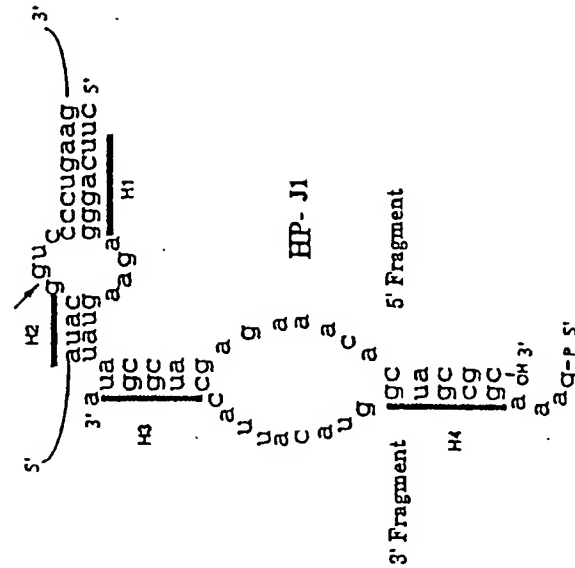


FIG. 65a.

Substrate RNA (site J)



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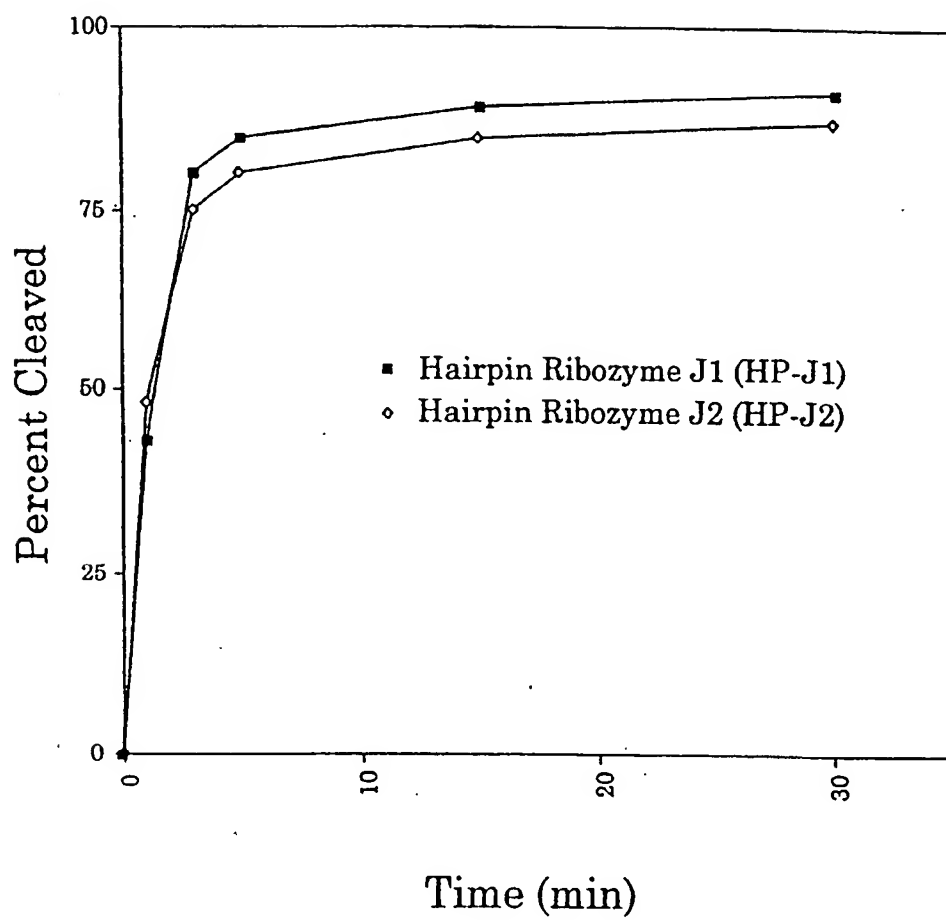


FIG. 66.

FIG. 67b.

Substrate RNA

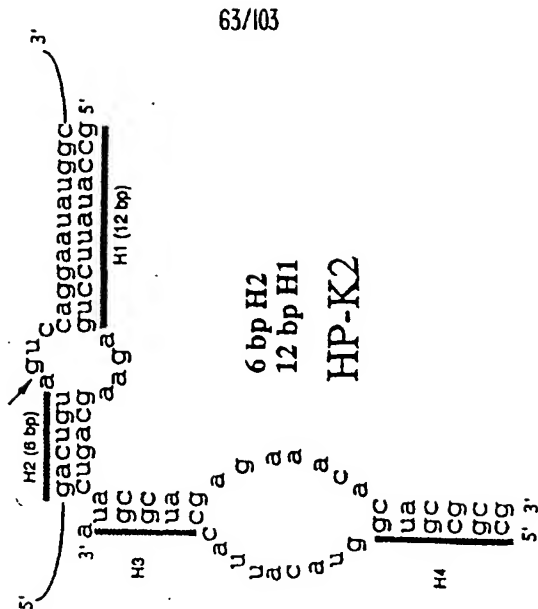
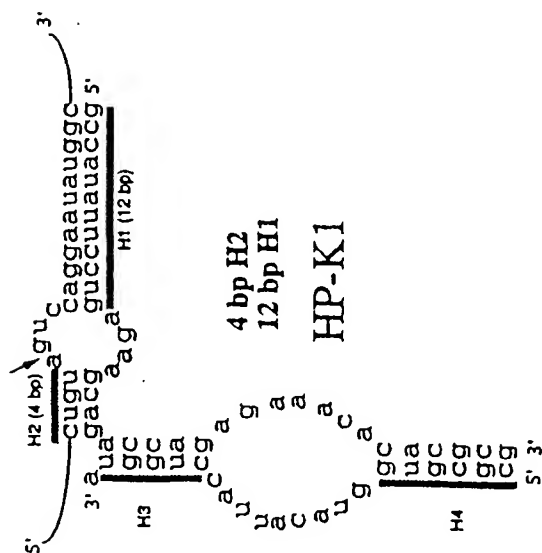


FIG. 67a.

Substrate RNA



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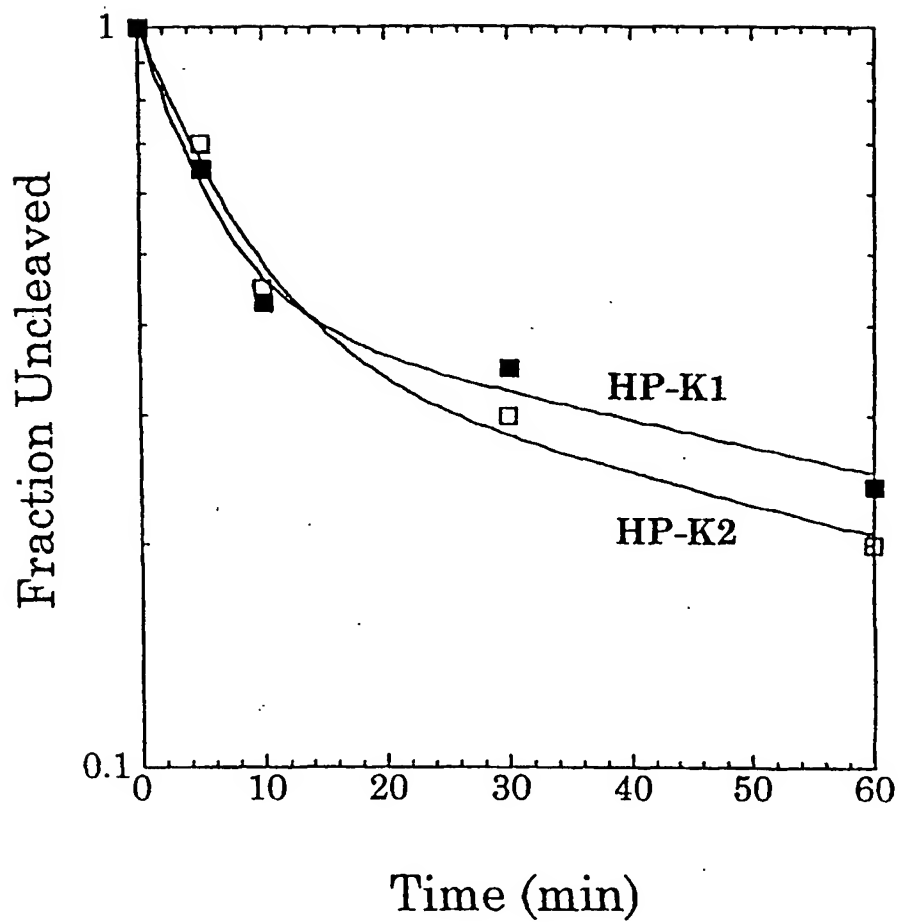


FIG. 68.

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FIG. 69b.

Substrate RNA

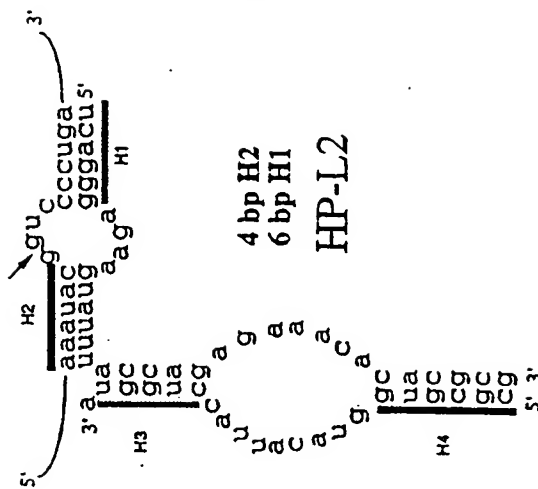
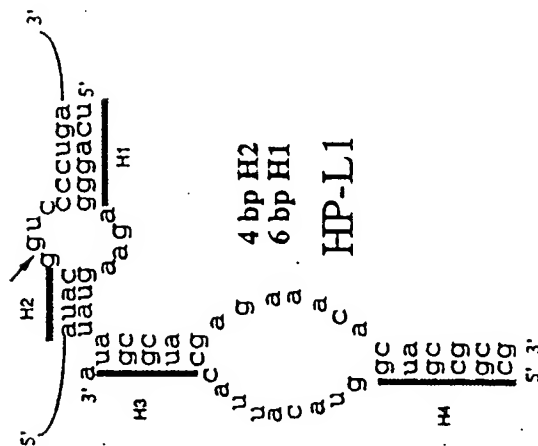


FIG. 69a.

Substrate RNA



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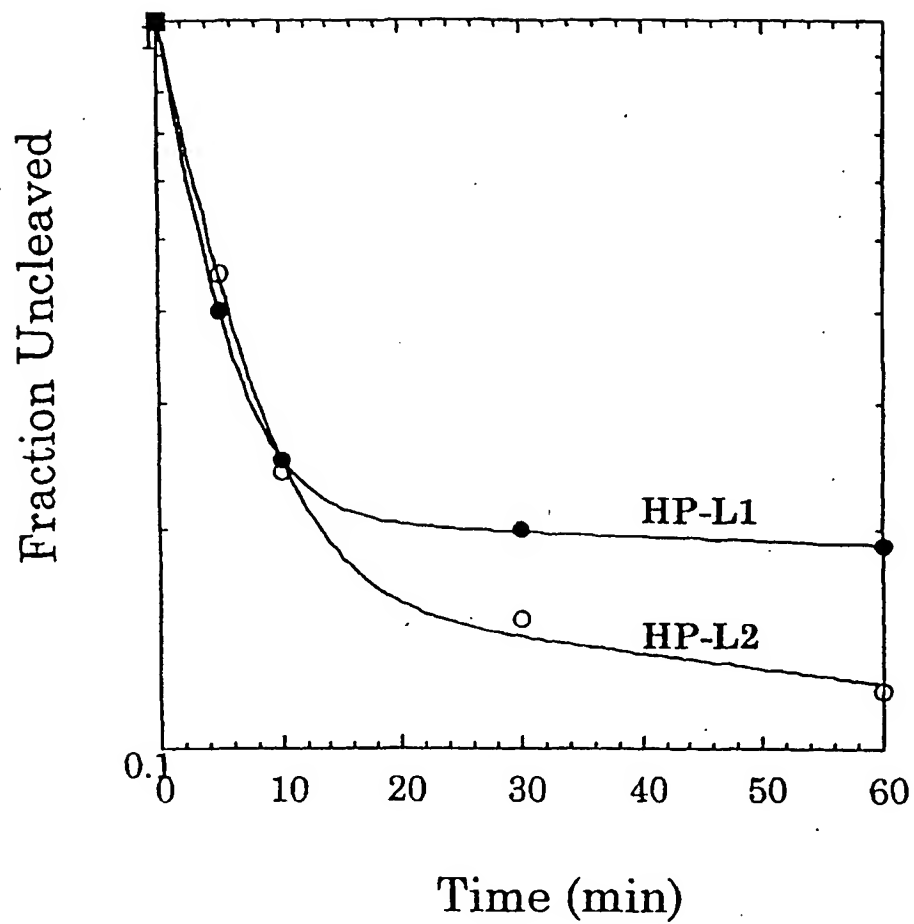


FIG. 70.



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FIG. 71b.

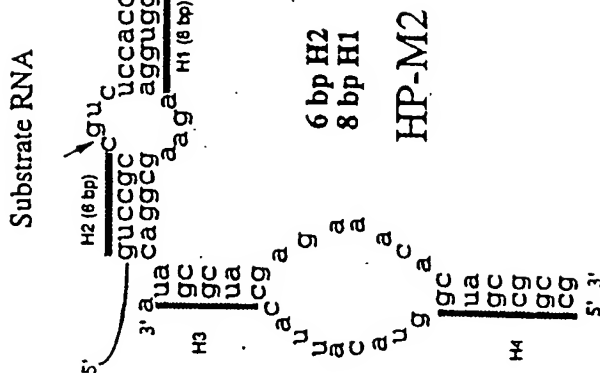
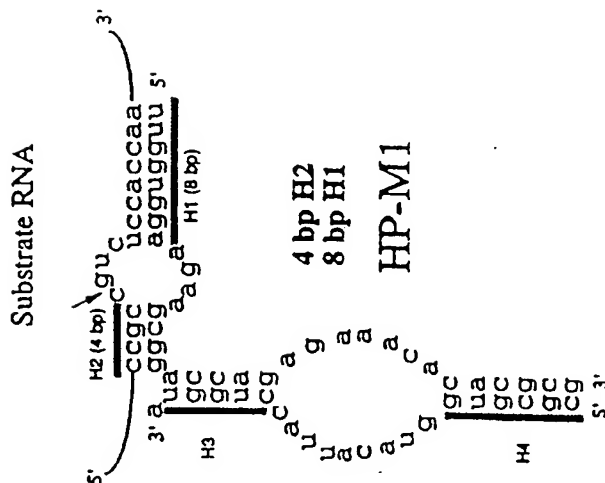


FIG. 71a.



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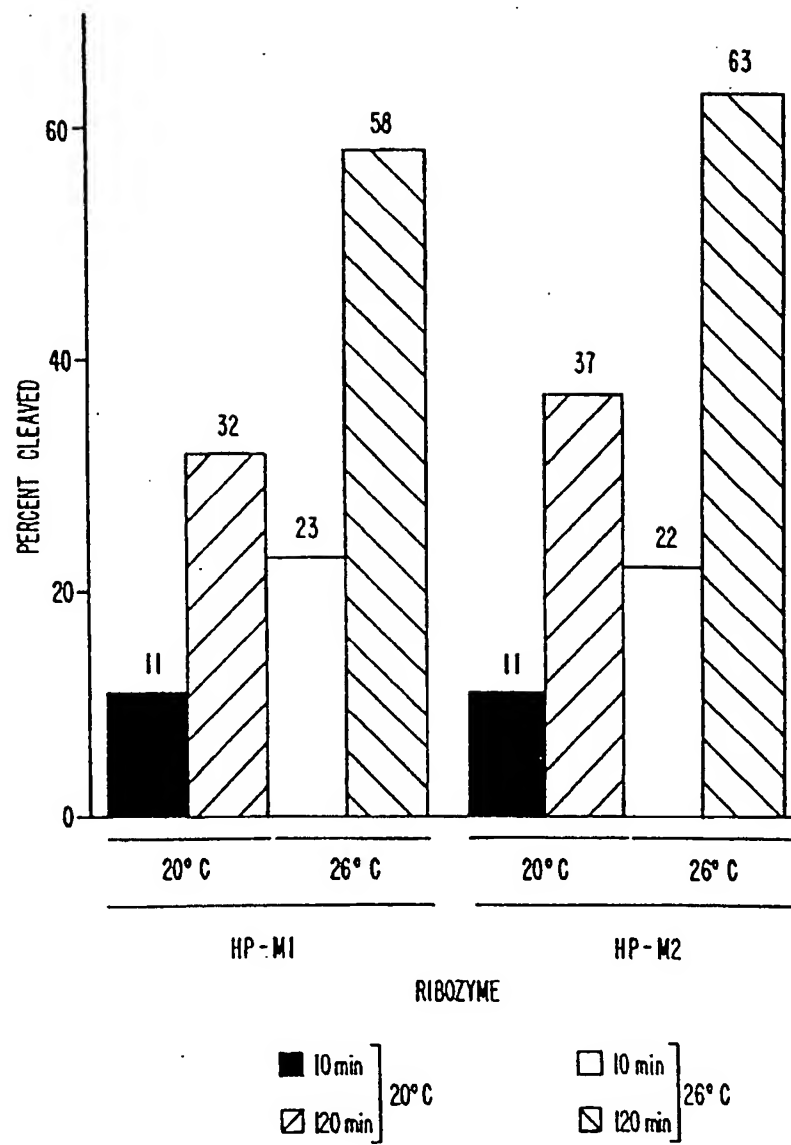
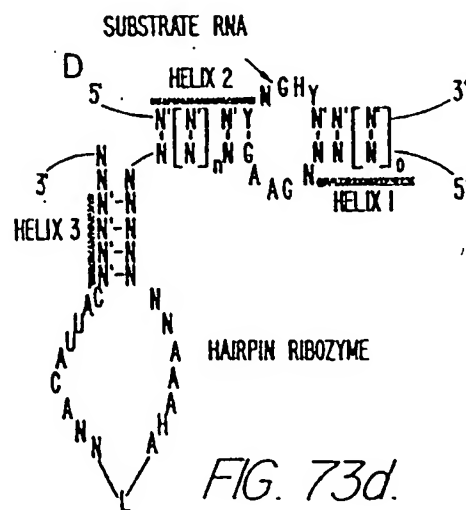
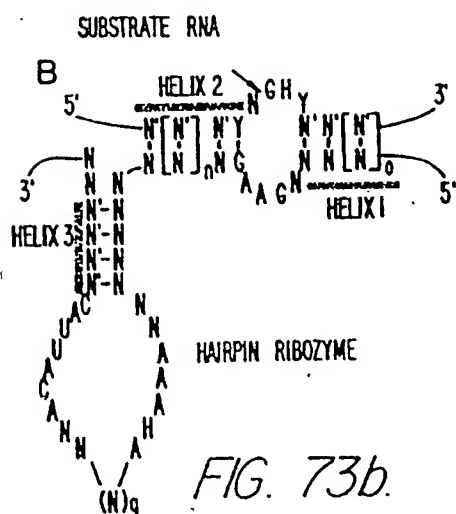
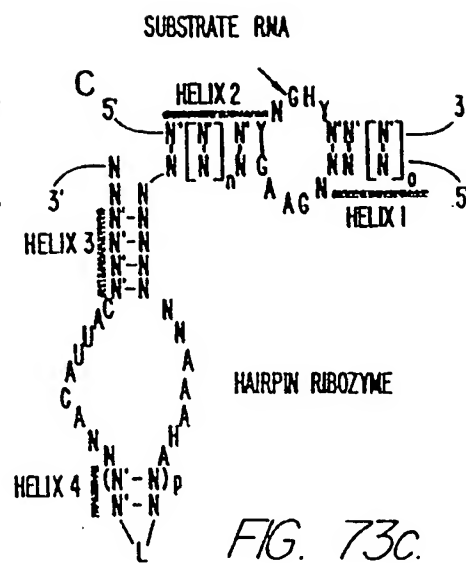
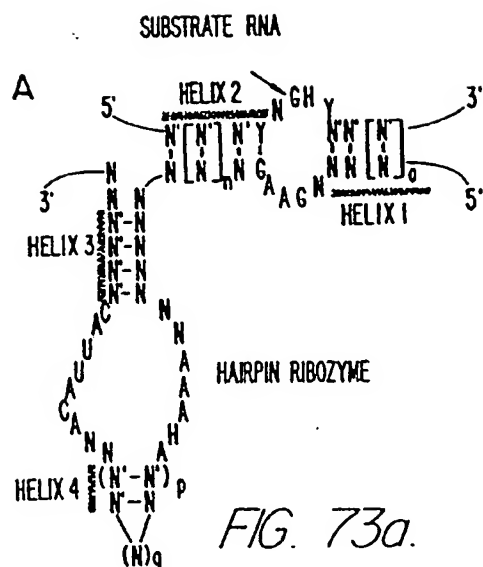


FIG. 72.

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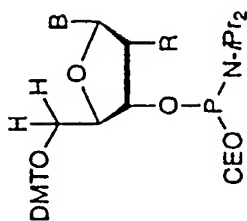
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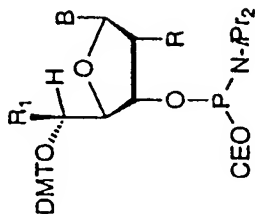
FIG. 75a.



1

D-Ribose Family

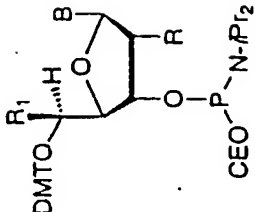
FIG. 75b.



2

D-Allose Family

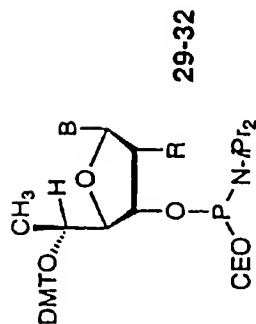
FIG. 75c.



3

L-Talose Family

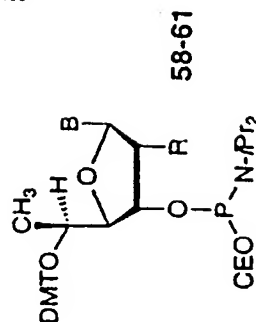
FIG. 75d.



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D-Allose

FIG. 75e.



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L-Talose

B = Protected A, C, G, U, T, 2AP, I, DIAP, P etc.

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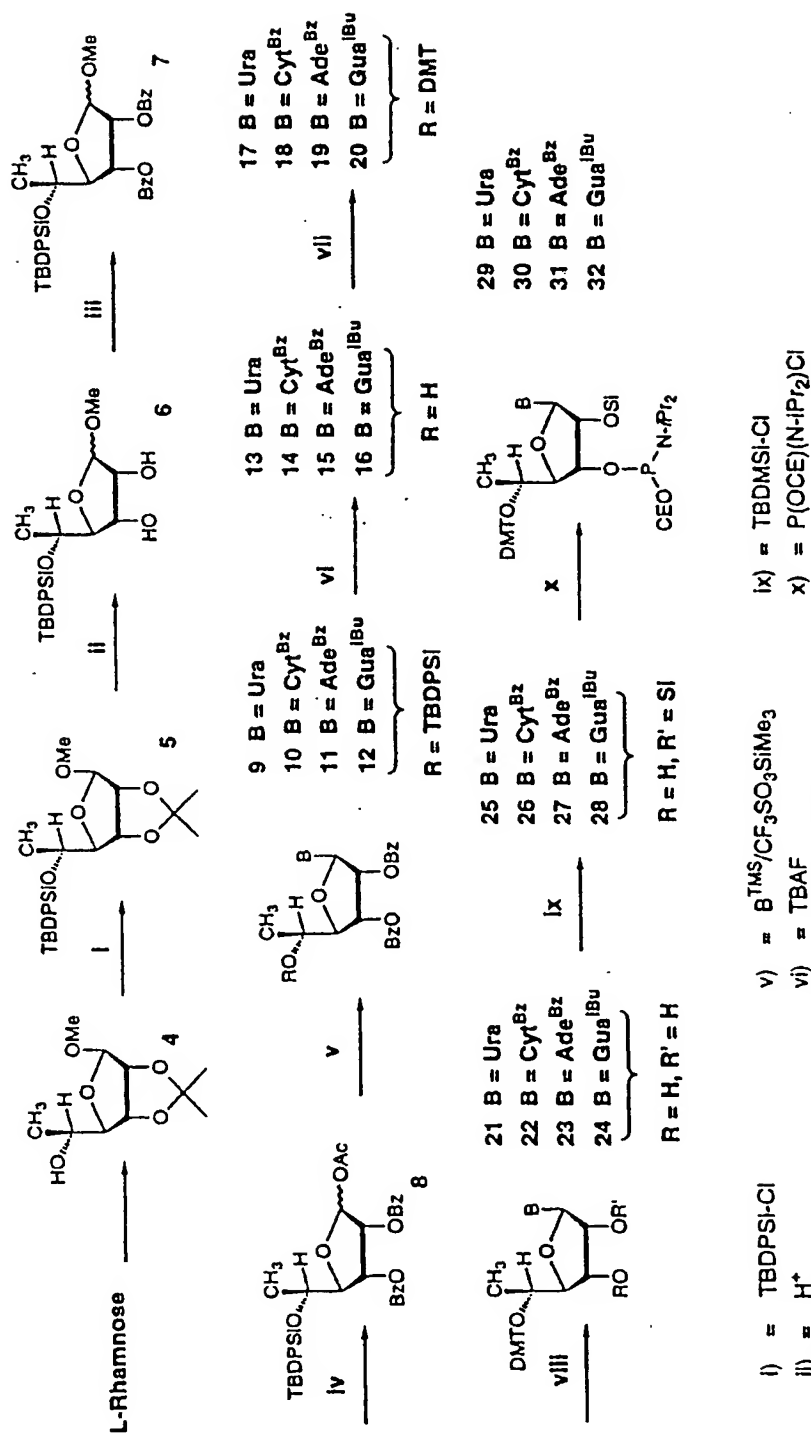


FIG. 76.

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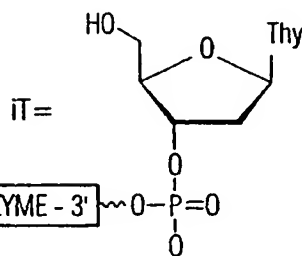
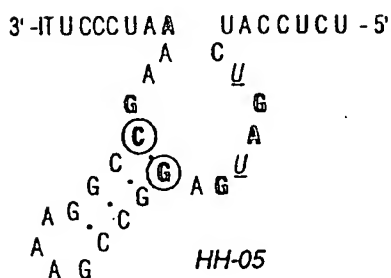
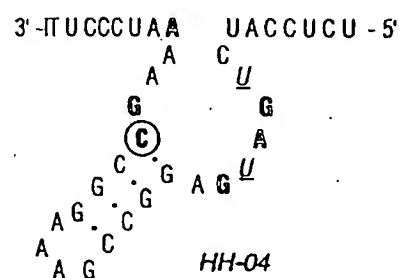
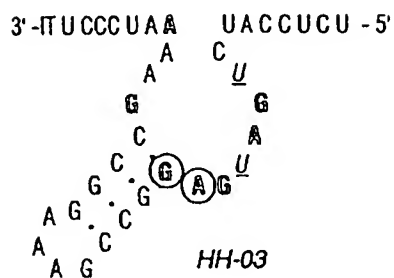
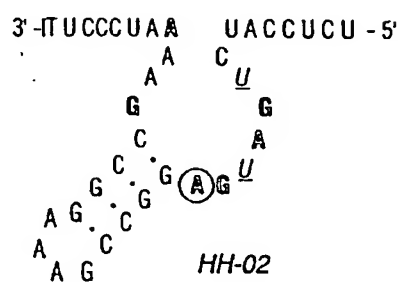
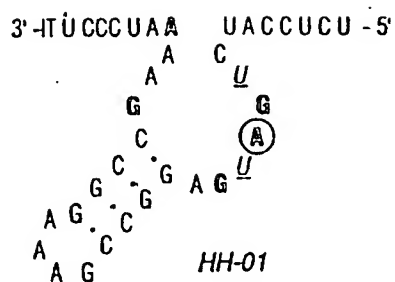
[illegible]
$$\begin{aligned} \text{ix)} &= \text{OH}^+ \\ \text{x)} &= \text{TBDMSI-Cl} \\ \text{xi)} &= \text{P(OCE)(N-IPr}_2\text{)Cl} \end{aligned}$$

i)	=	Ph <sub>3</sub> P/DEAD/p-NO <sub>2</sub> PhCOOH	v)	=	AcOH/Ac <sub>2</sub> O/H <sup>+</sup>
ii)	=	OH <sup>+</sup> , TBDPSI-Cl	vi)	=	B <sup>TMS</sup> /CF <sub>3</sub> SO <sub>3</sub> SiH <sup>+</sup>
iii)	=	H <sup>+</sup>	vii)	=	TBAF
iv)	=	Bz-Cu/Pyr	viii)	=	DMT-Cu/AgNO <sub>3</sub>

FIG 77

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FIG. 78.



N=2'-O-Me

N=RIBO

U=2'-NH<sub>2</sub>U

(N)=TALO

WHERE THE ALPHABET "N" REPRESENTS A NUCLEOTIDE, A, U, G, OR C  
SUBSTITUTE SHEET (RULE 26)

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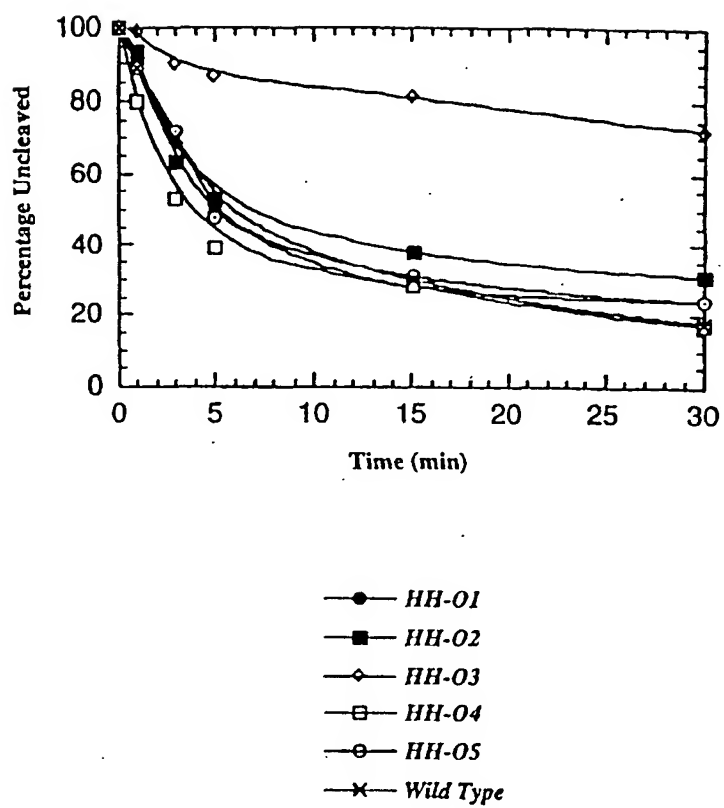


FIG. 79.

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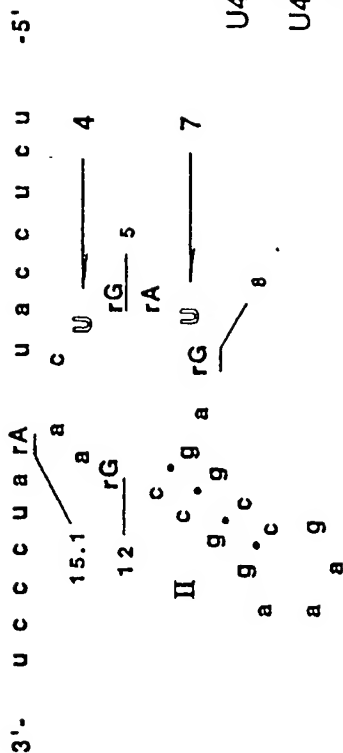


Table 1 Entries

U4 & U7 = 2'-C-Allyl-U	12-14
U4 & U7 = 2'-F-ribo-U	9-11
U4 & U7 = 2'=CH <sub>2</sub> -U	3-5
U4 & U7 = 2'=CF <sub>2</sub> -U	6-8
U4 & U7 = 2'-dU	21-22
U4 & U7 = 2'-F-ara-U	15-17
U4 & U7 = 2'-NH <sub>2</sub> -U	18-20
U4 & U7 = 2'-O-Me-ribo-U	2

Lower case = 2'-O-Me  
rN = ribonucleotide

FIG. 80.

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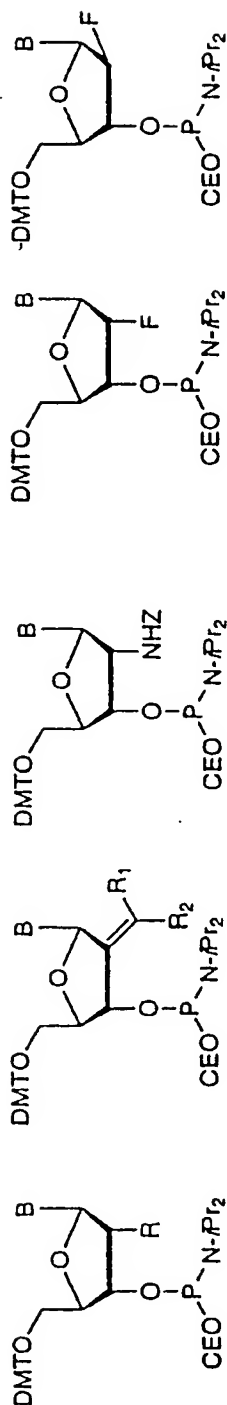


FIG. 8Ia.

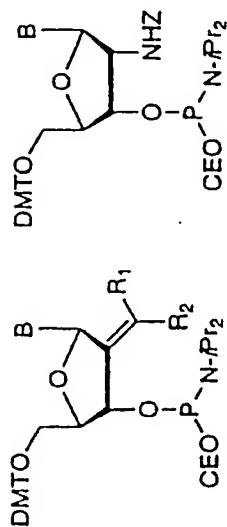


FIG. 8Ib.

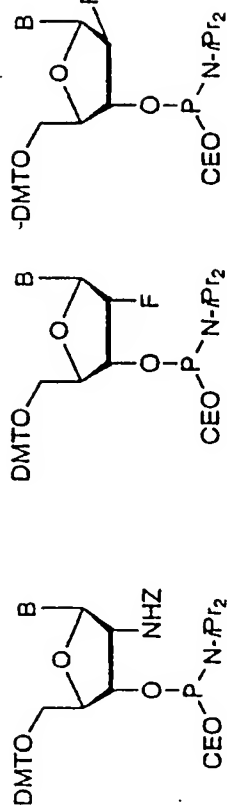


FIG. 8Ic.

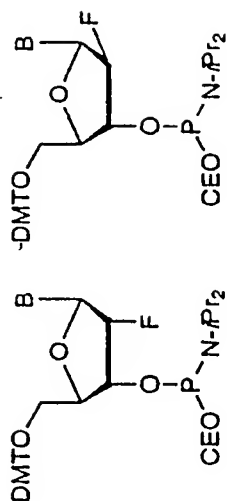


FIG. 8Id.

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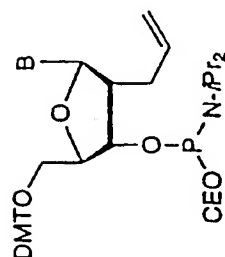


FIG. 8If.

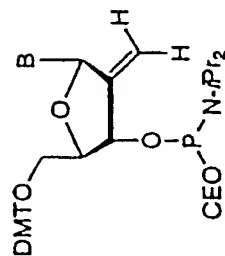


FIG. 8Ig.

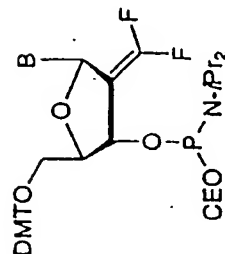


FIG. 8Ih.

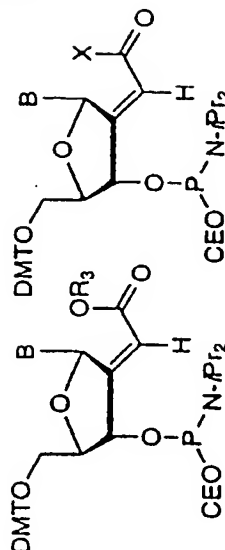


FIG. 8Ii.

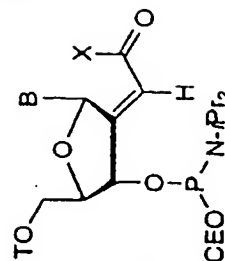


FIG. 8Ij.

B = Protected A, C, G, U, T, 2AP, I, DIAP, P etc.

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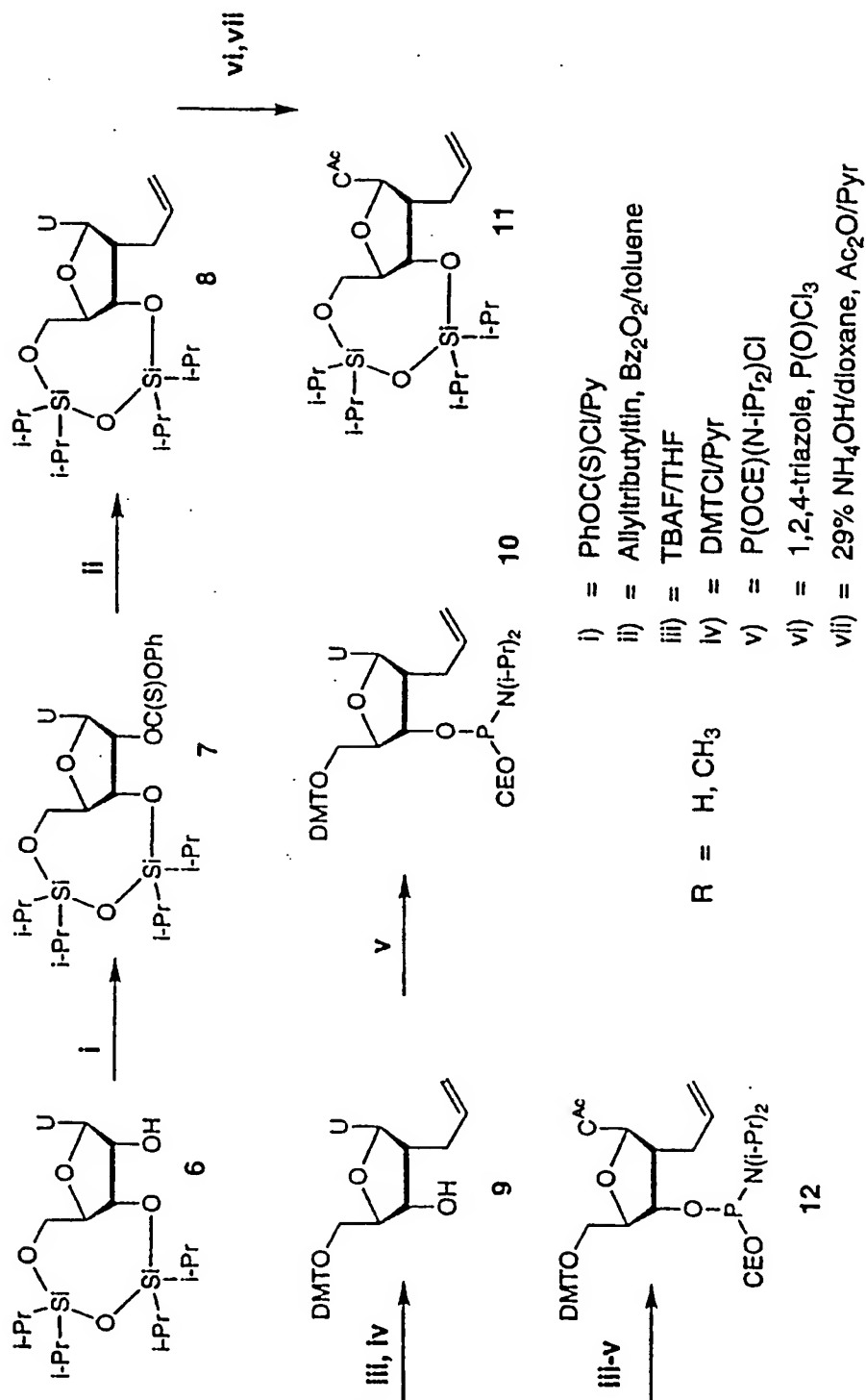


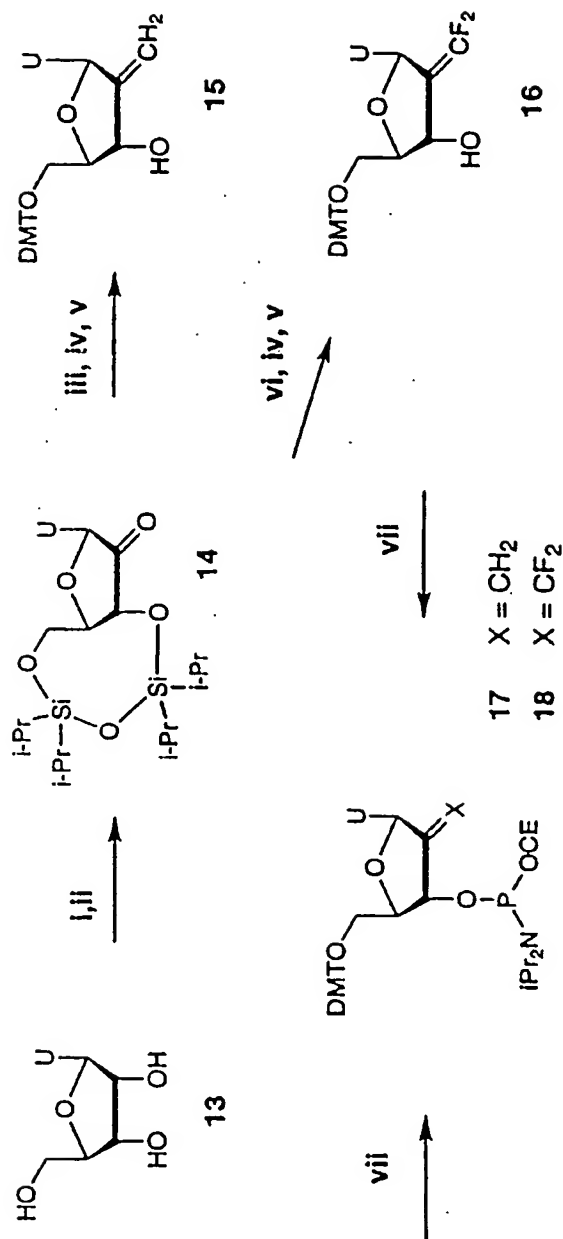
FIG. 82.

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FIG. 83.



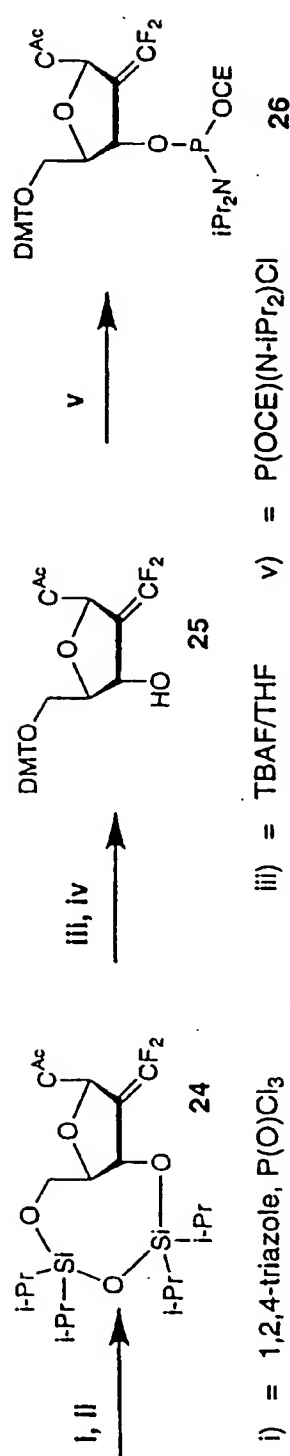
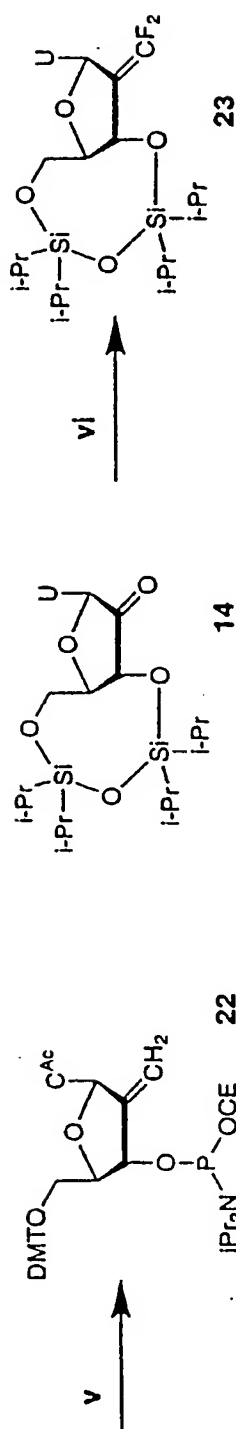
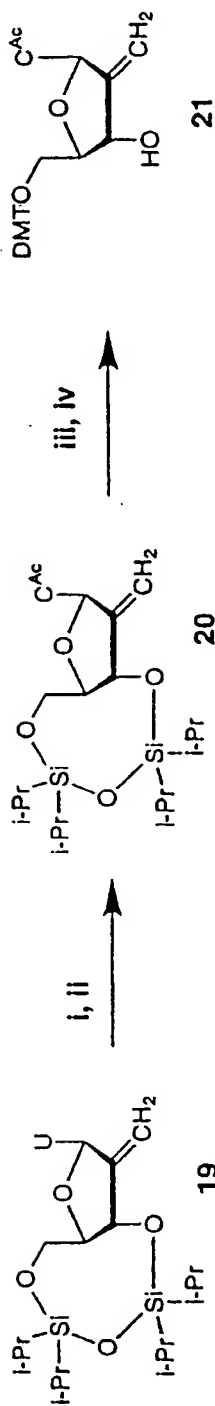
- i) = Markiewicz reagent  
 ii) = DMSO & Ac<sub>2</sub>O  
 iii) = Ph<sub>3</sub>PCH<sub>3</sub>I  
 iv) = TBAF/THF  
 v) = DMTCI/Pyr  
 vi) = Ph<sub>3</sub>P, ClCF<sub>2</sub>COONa  
 vii) = P(OCE)(N-iPr<sub>2</sub>)Cl

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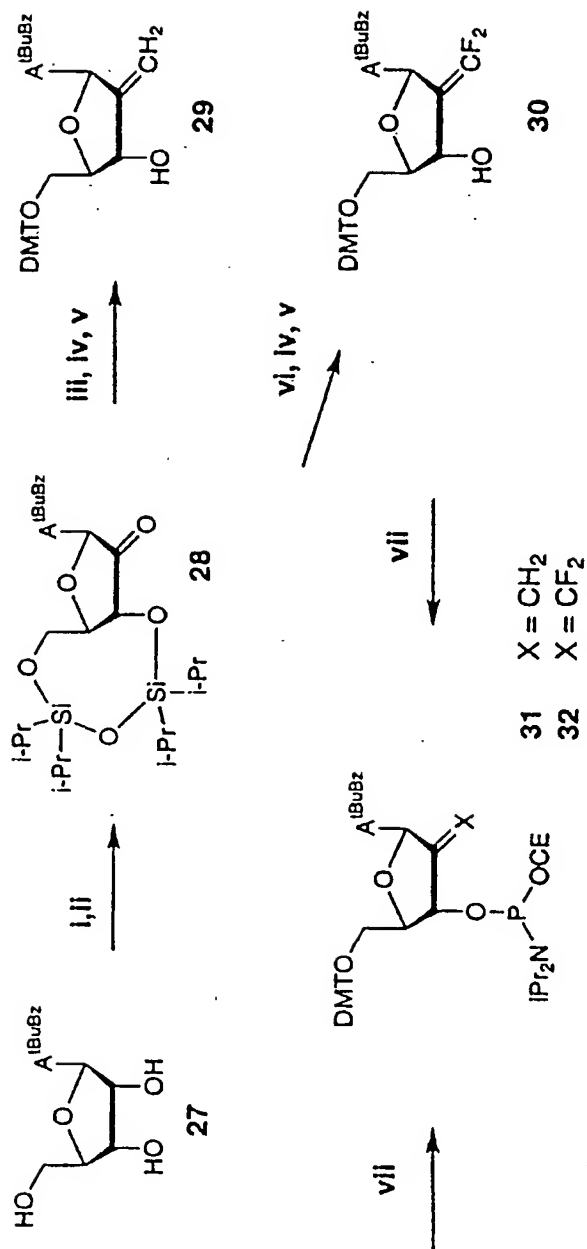
FIG. 84.



i) = 1,2,4-triazole,  $\text{P}(\text{O})\text{Cl}_3$   
 ii) = 29%  $\text{NH}_4\text{OH}$ /dioxane,  $\text{Ac}_2\text{O}$ /Pyr  
 iii) = TBAF/THF  
 iv) = DMTCl/Pyr  
 v) =  $\text{P}(\text{OCE})(\text{N}-i\text{Pr}_2)\text{Cl}$   
 vi) =  $\text{Ph}_3\text{P}$ ,  $\text{ClCF}_2\text{COONa}$

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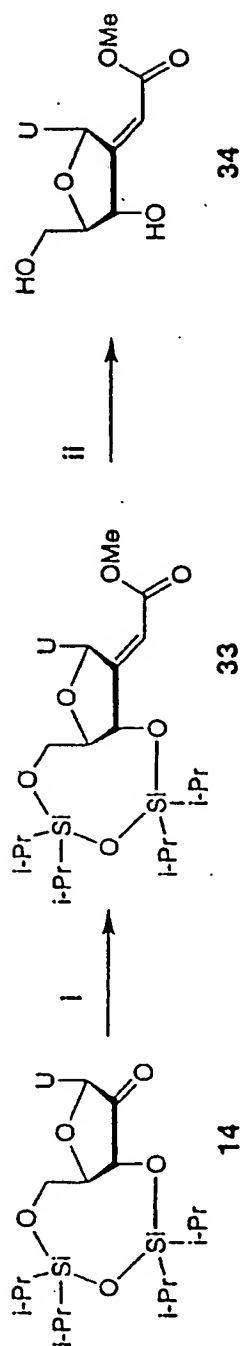
- i) = Markiewicz reagent  
 ii) = DMSO &  $\text{Ac}_2\text{O}$   
 iii) =  $\text{Ph}_3\text{PCH}_3\text{I}$   
 iv) = TBAF/THF  
 v) = DMTCI/Pyr  
 vi) =  $\text{Ph}_3\text{P}$ ,  $\text{ClCF}_2\text{COONa}$   
 vii) =  $\text{P}(\text{OCE})(\text{N-iPr}_2)\text{Cl}$

FIG. 85.

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i) =  $\text{Ph}_3\text{PC}=\text{CHC}(\text{O})\text{OCH}_3\cdot\text{OAc}$   
 ii) =  $\text{NEt}_3\cdot 3 \text{ HF}$   
 iii) =  $\text{DMTCI/Pyr}$   
 iv) =  $\text{P}(\text{OCE})(\text{N-IPr}_2)\text{Cl}$   
 v) =  $\text{MeOH/NaOH}$

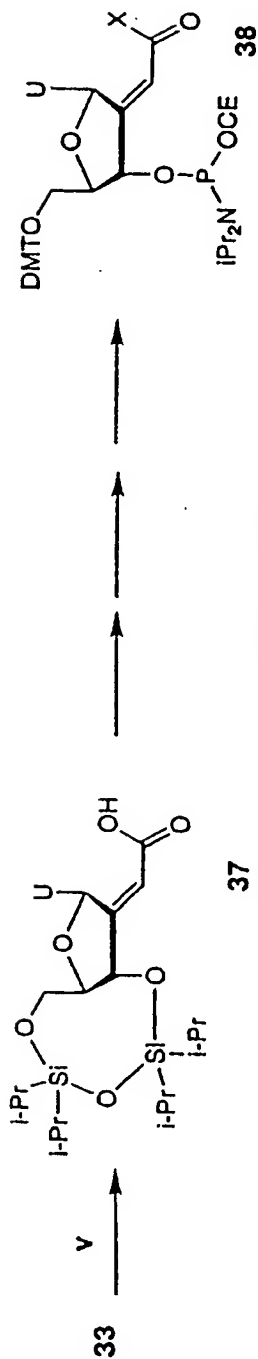
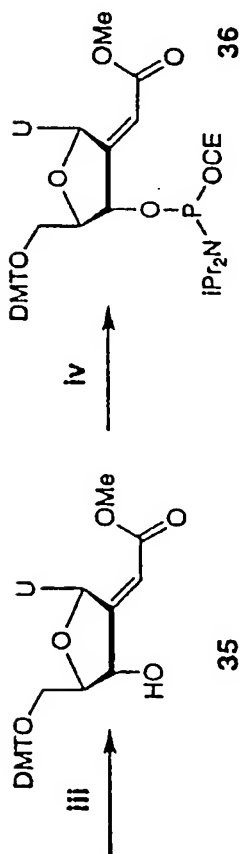
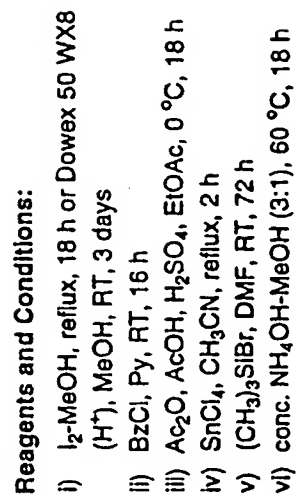


FIG. 86.

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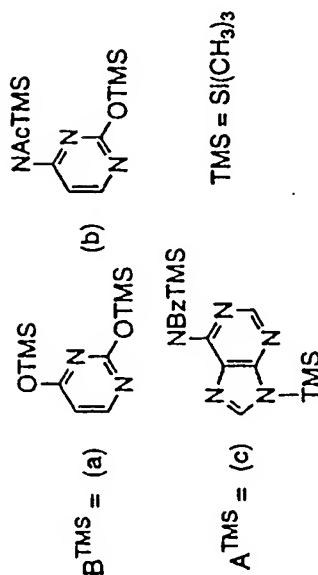


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### Reagents and Conditions:

- i)  $\text{I}_2$ -MeOH, reflux, 18 h or Dowex 50 WX8 ( $\text{H}^+$ ), MeOH, RT, 3 days
- ii)  $\text{BzCl}$ , Py, RT, 16 h
- iii)  $\text{Ac}_2\text{O}$ , AcOH,  $\text{H}_2\text{SO}_4$ , EtOAc,  $0^\circ\text{C}$ , 18 h
- iv)  $\text{SnCl}_4$ ,  $\text{CH}_3\text{CN}$ , reflux, 2 h
- v)  $(\text{CH}_3)_3\text{SiBr}$ , DMF, RT, 72 h
- vi) conc.  $\text{NH}_4\text{OH}$ -MeOH (3:1),  $60^\circ\text{C}$ , 18 h

 $\text{B}^{\text{TMS}} = (\text{a})$ 
$$\text{TMS} = \text{Si}(\text{CH}_3)_3$$
$$A^{\text{TMS}} = (\text{c})$$

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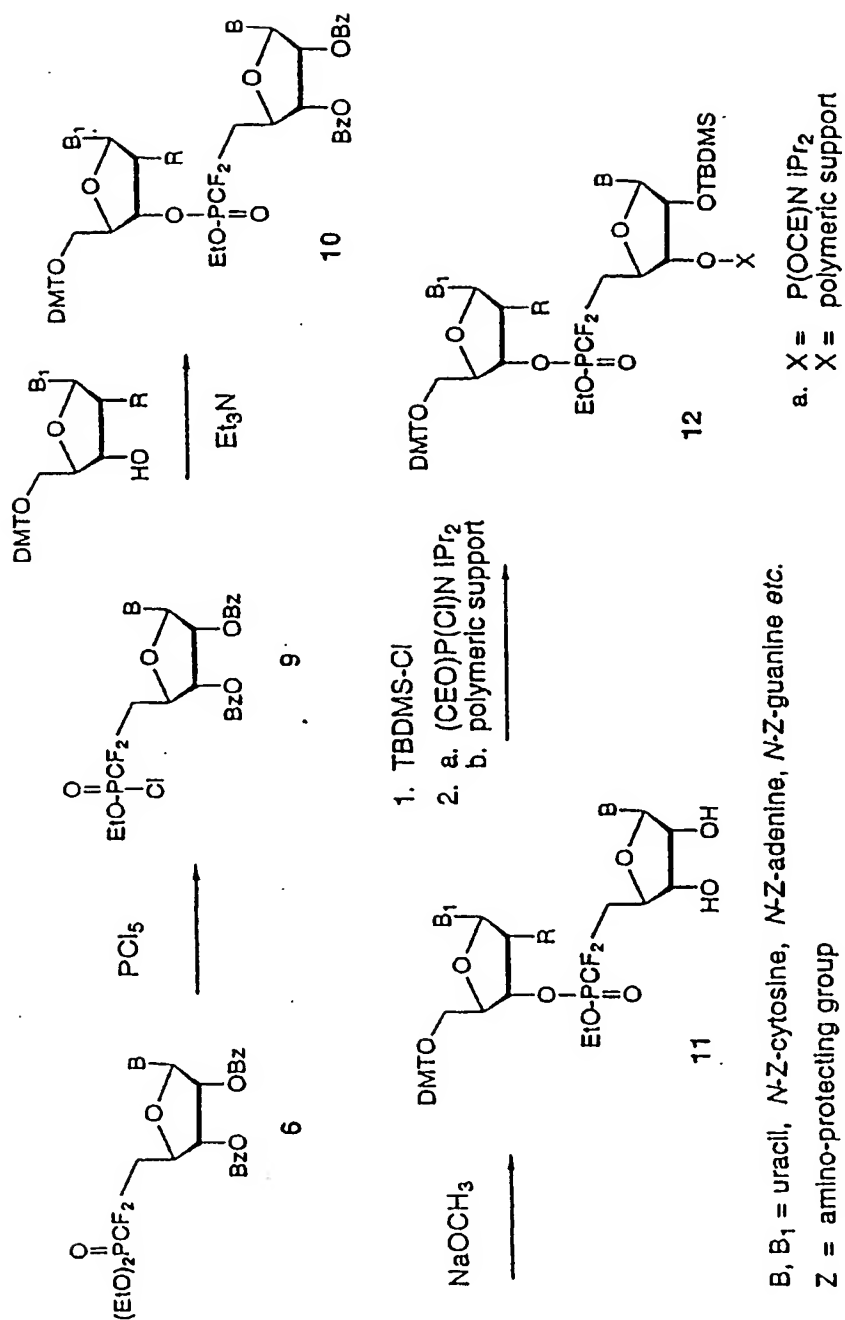
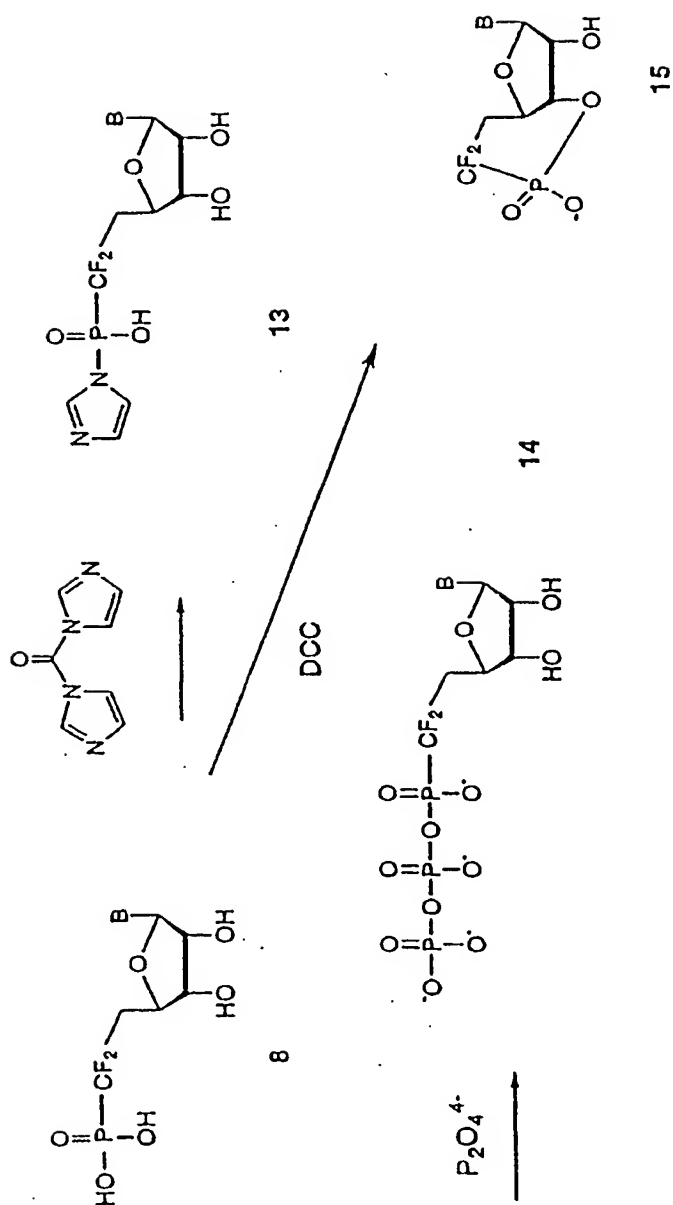


FIG. 88.

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B = uracil, N-Z-cytosine, N-Z-adenine, N-Z-guanine etc.

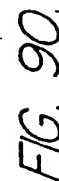
Z = amino-protecting group

FIG. 89.

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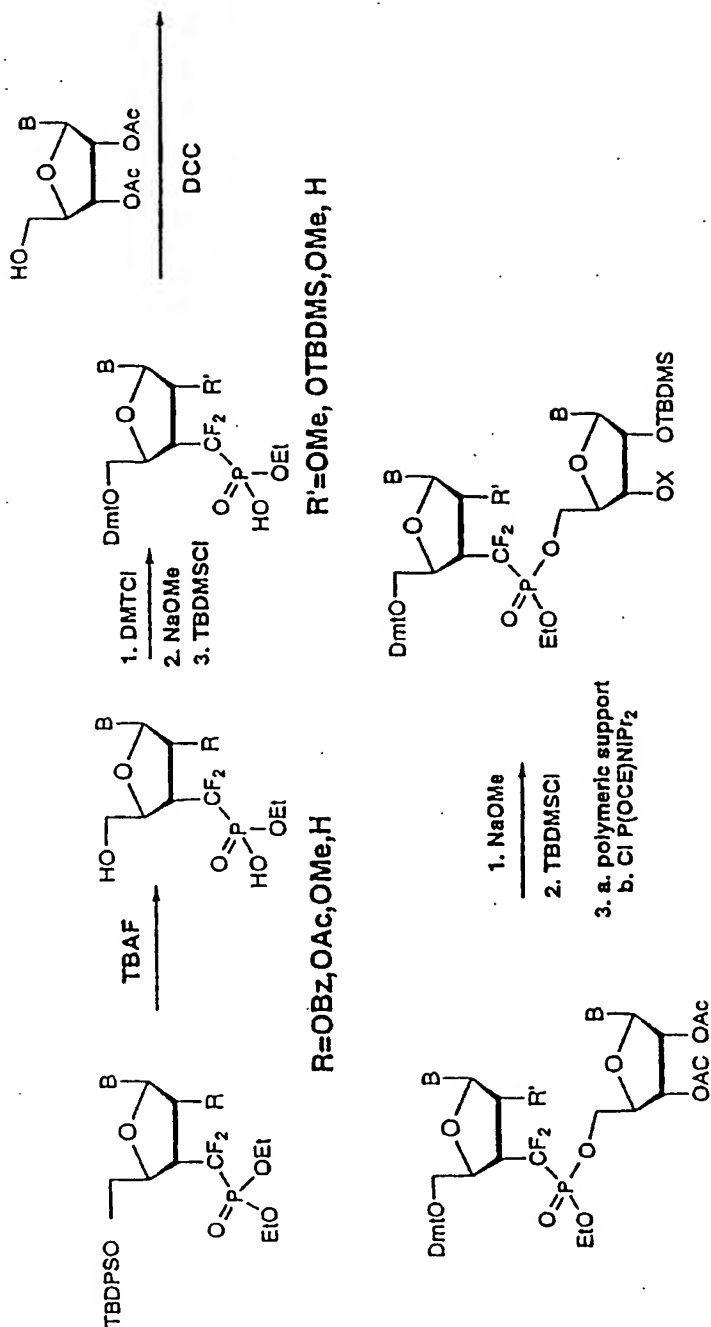
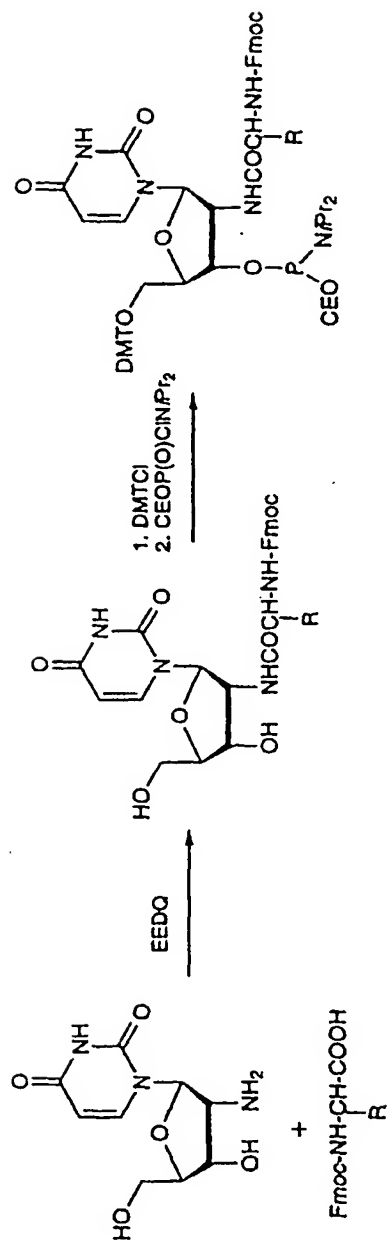


FIG. 91.

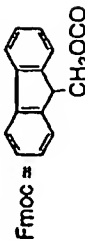
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EEDQ = N-ethoxycarbonyl-2-ethoxy-1,2-dihydroquinoline



R = CH<sub>3</sub>, CH<sub>2</sub>-, (CH<sub>2</sub>)<sub>4</sub>NH-Fmoc, (CH<sub>2</sub>)<sub>4</sub>NH-CBZ, CH<sub>2</sub>COOBzl  
 (ala) (phe) (lys) (asp)

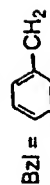
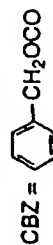
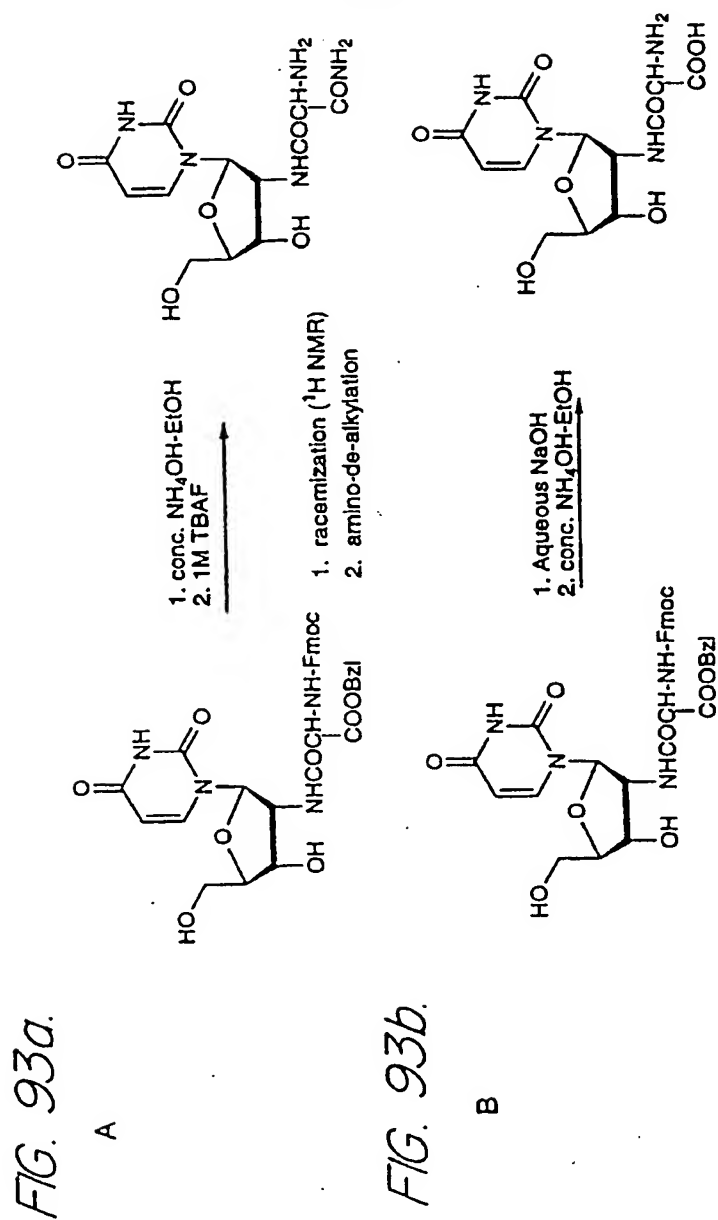


FIG. 92.

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*FIG. 93b.*

B

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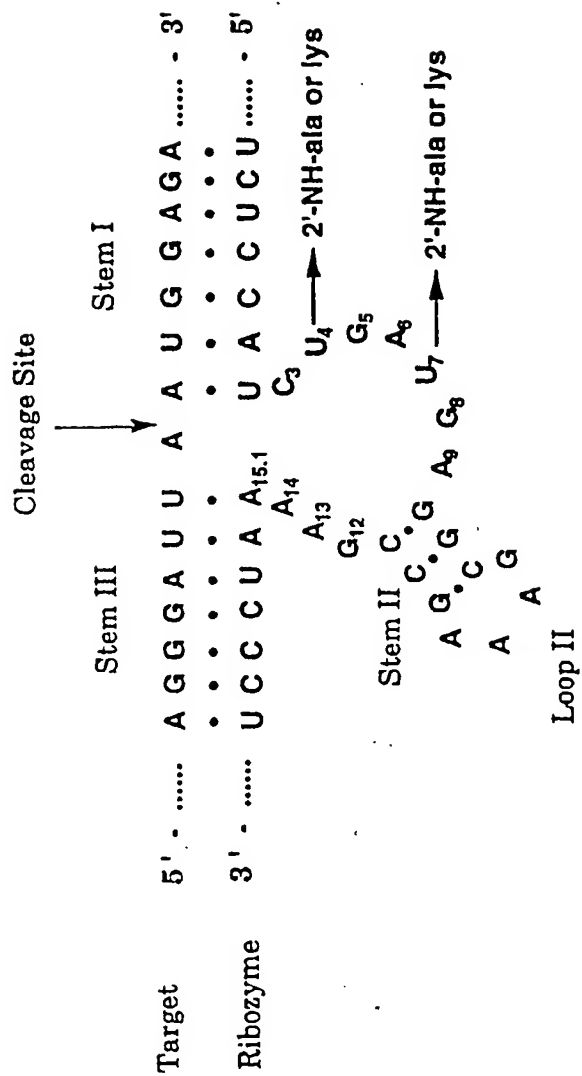
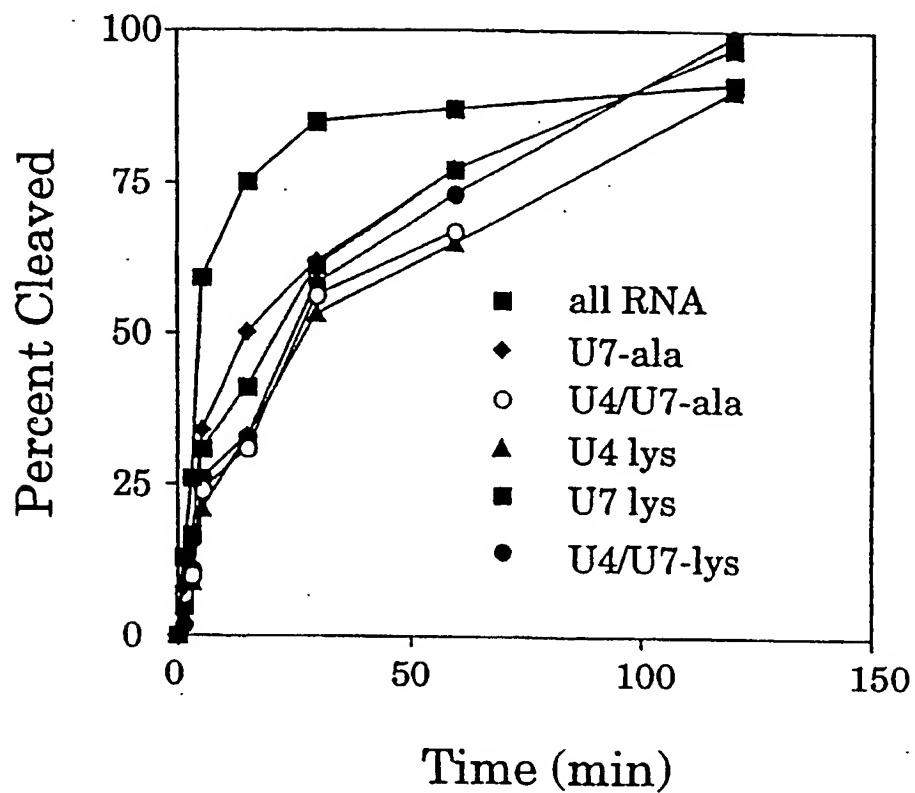


FIG. 94.



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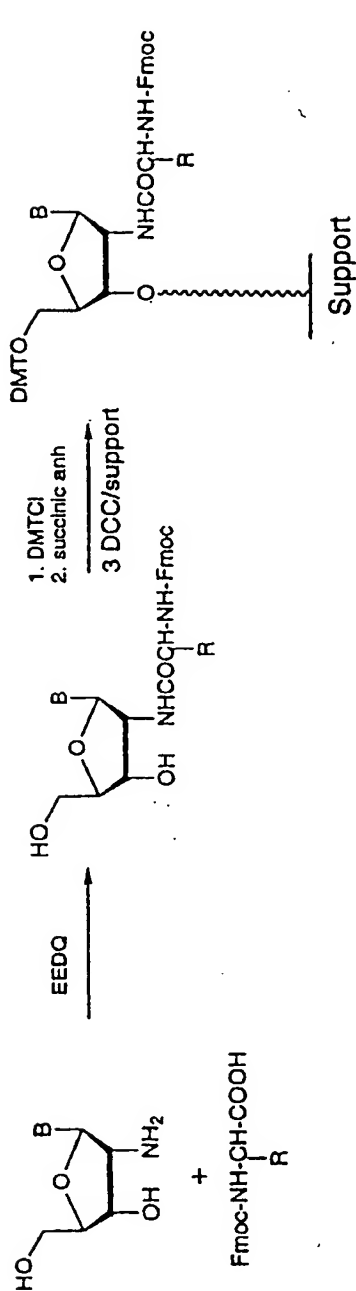
[Ribozyme] = 40 nM [Substrate] = ~1nM

FIG. 95.

SUBSTITUTE SHEET (RULE 26)

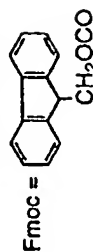
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B = Ura, Cyt<sup>bz</sup>, Ade<sup>bz</sup>, Gua<sup>ibu</sup>, mod. base, H

EEDQ = N-ethoxycarbonyl-2-ethoxy-1,2-dihydroquinoline



R = CH<sub>3</sub>, CH<sub>2</sub>-C<sub>6</sub>H<sub>5</sub> (phe), (CH<sub>2</sub>)<sub>4</sub>NH-Fmoc, (CH<sub>2</sub>)<sub>4</sub>NH-CBZ, CH<sub>2</sub>COOBzl (lys), (asp)

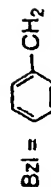
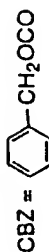


FIG. 96.

SUBSTITUTE SHEET (RULE 26)

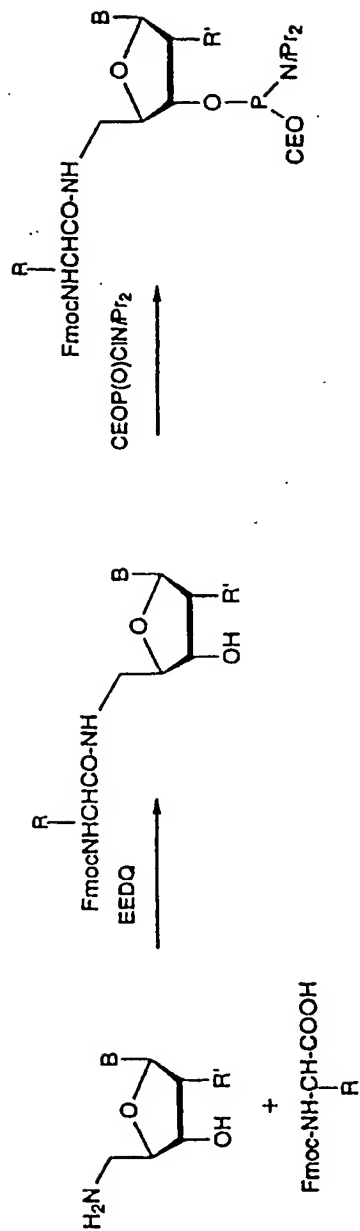
NUC 37999

FIG. 97.

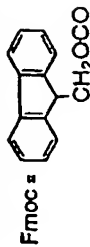


B= Ura, Cyt<sup>bz</sup>, Ade<sup>bz</sup>, Gua<sup>ibu</sup>, mod. base, H

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EEDQ = N-ethoxycarbonyl-2-ethoxy-1,2-dihydroquinoline



R = CH<sub>3</sub>, CH<sub>2</sub>- (ala), (phe), (lys), (asp), (Gua<sup>ibu</sup>), (mod. base), H

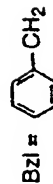
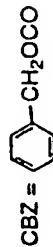


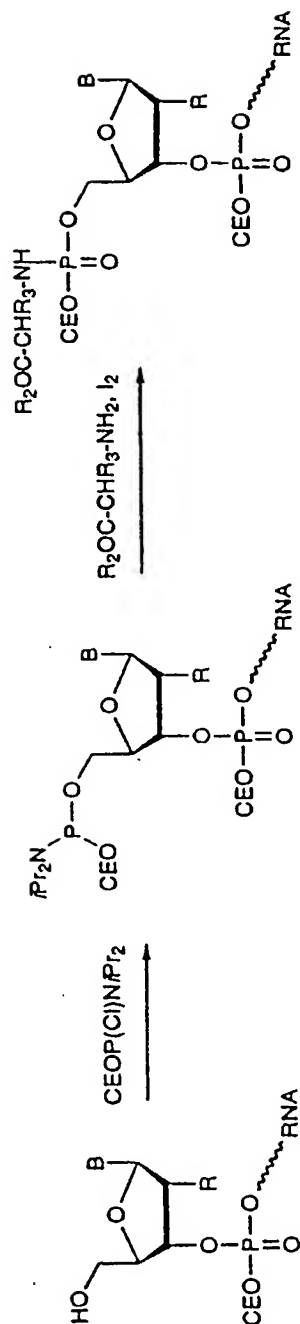
FIG. 98.

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FIG. 99.



B = Ura, Cyt<sup>bz</sup>, Ade<sup>bz</sup>, Gua<sup>ibu</sup>, mod. base, H  
 R = H, OCH<sub>3</sub>, OTBDMS, Hal, NHR<sub>1</sub>  
 R<sub>2</sub> = OBzl, peptidyl

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FIG. 100.

## Reversion of mutant RNA

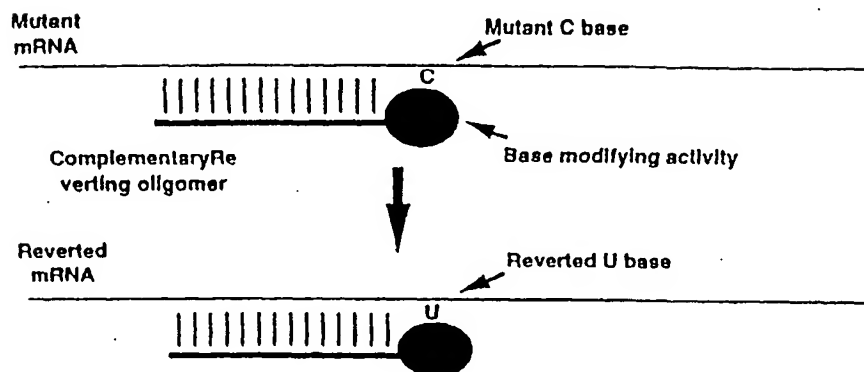
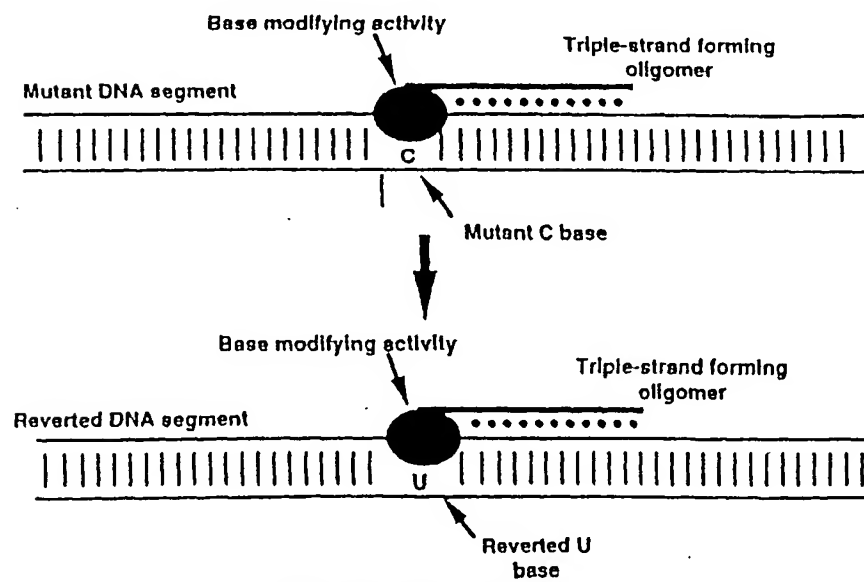


FIG. 101.

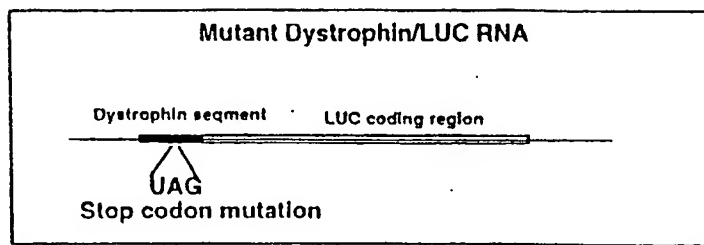
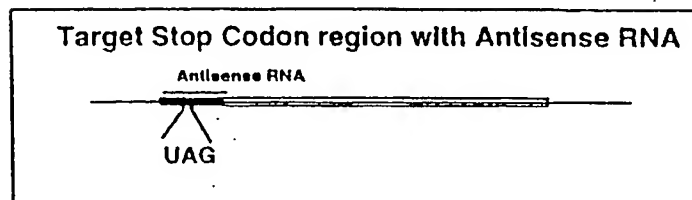
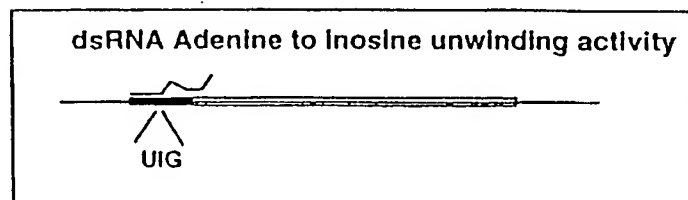
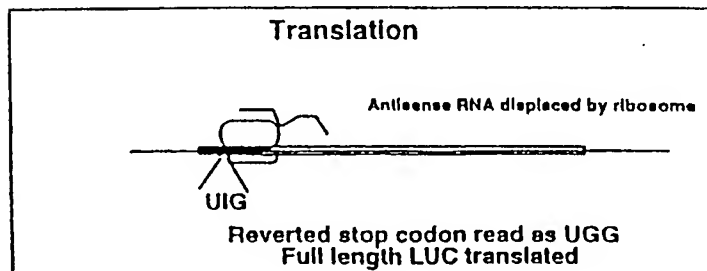
## Reversion of mutant DNA



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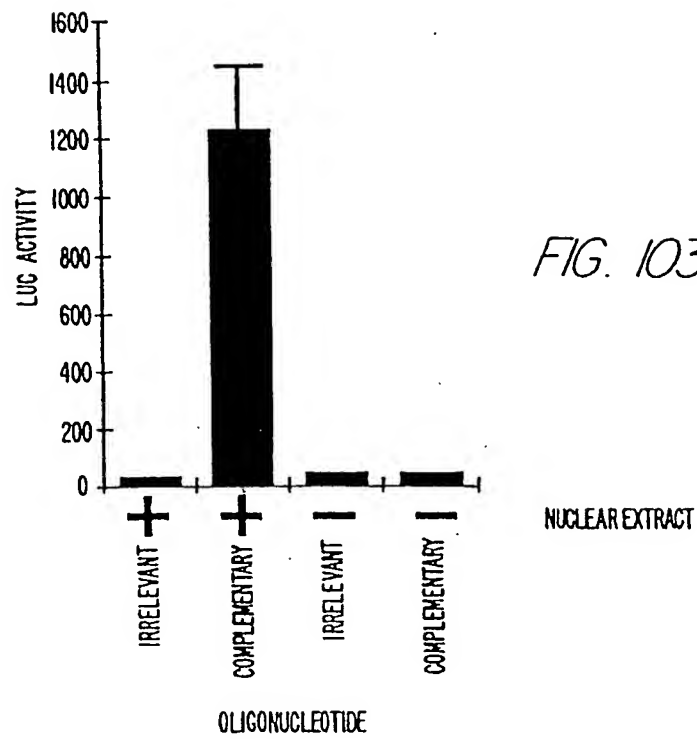
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*FIG. 102a.**FIG. 102b.**FIG. 102c.**FIG. 102d.*

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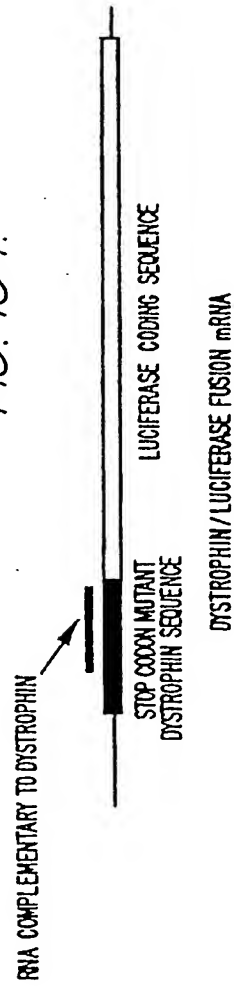
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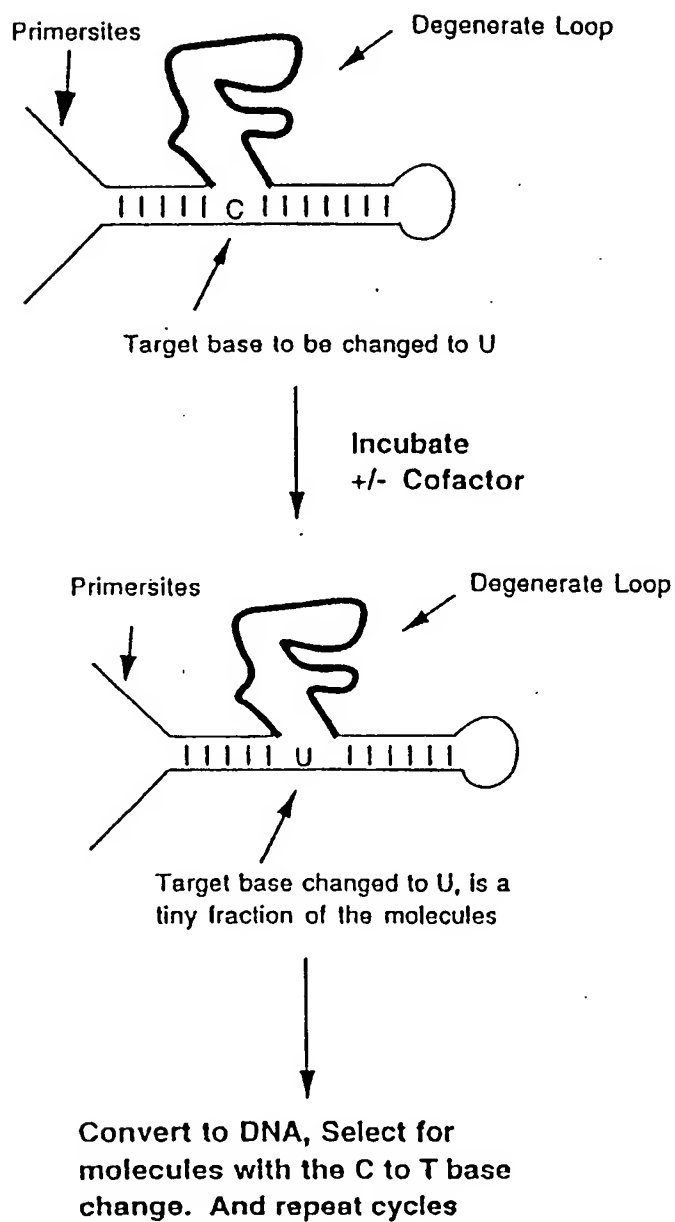
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FIG. 104.



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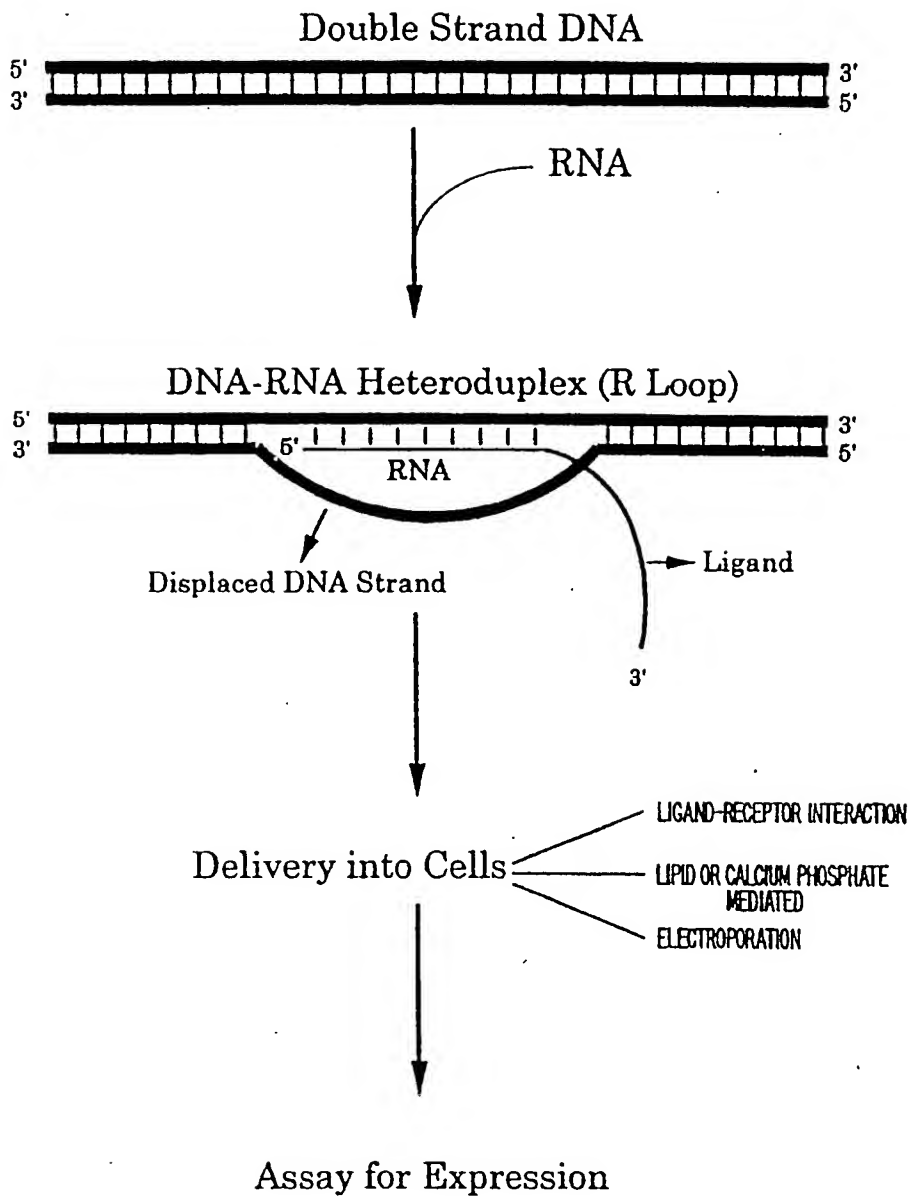
FIG. 105.



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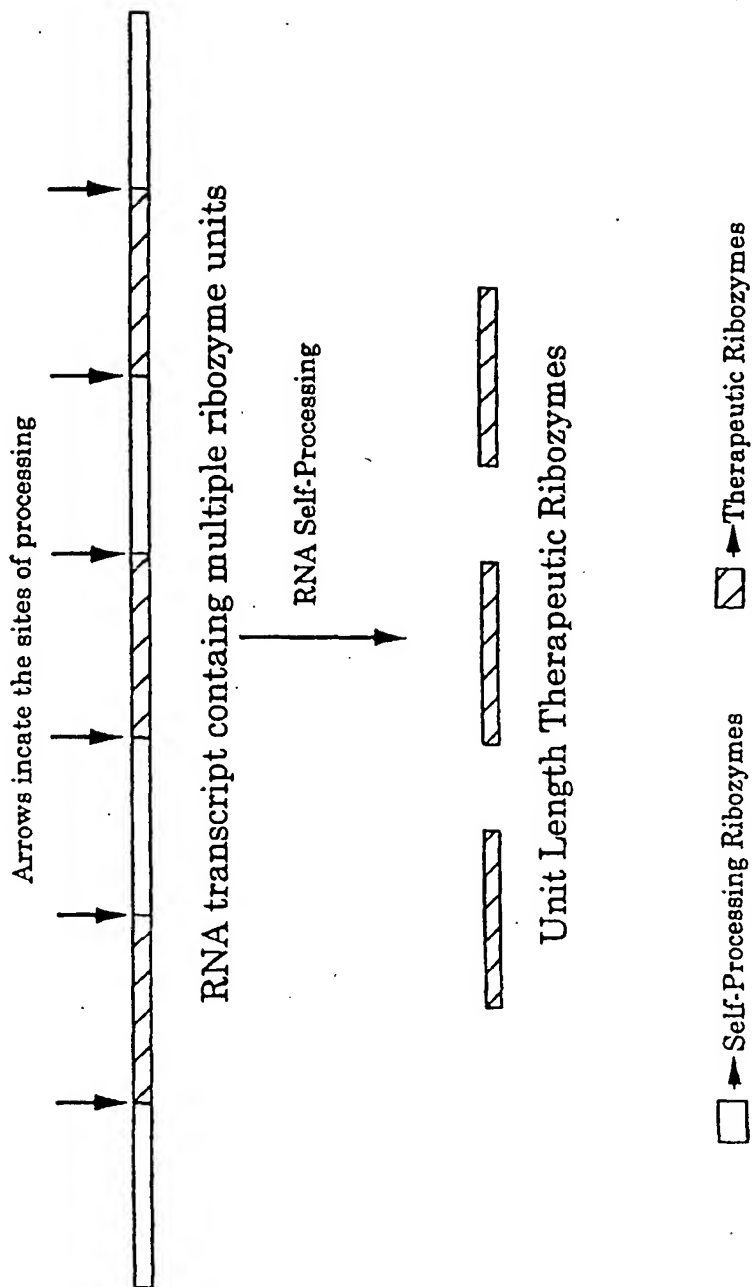
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*FIG. 106.*

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FIG. 107



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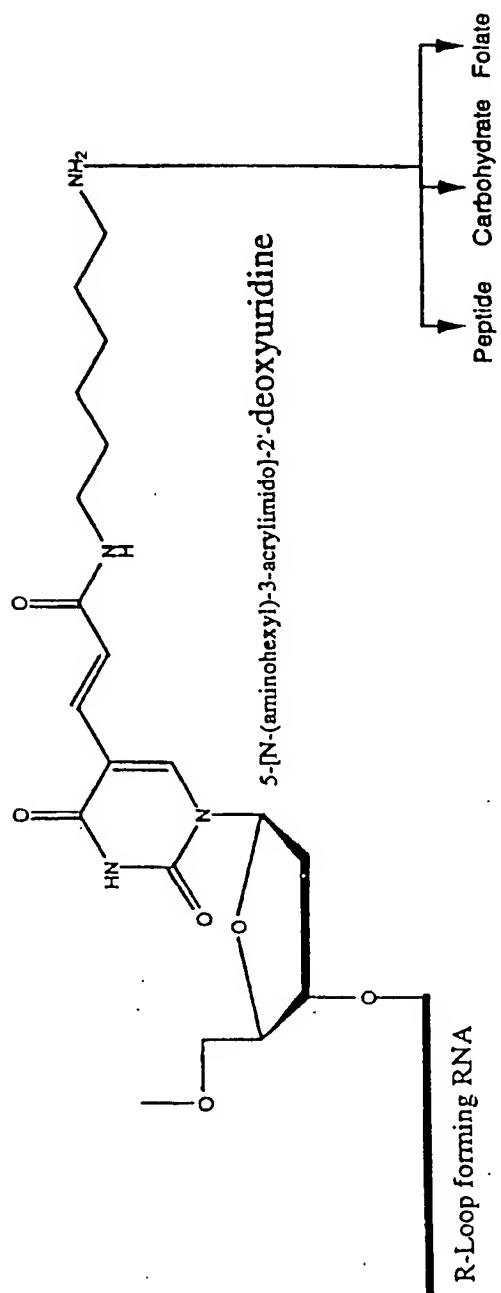


FIG. 108.

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